MAPPING THE ENERGY LANDSCAPE OF WATER AND WASTEWATER TREATMENT PLANTS IN THE STATE OF FLORIDA

Dr. S.A. Sherif, Professor and Director UF-IAC
Dr. C. Cardenas-Lailhacar, Assistant Director UF-IAC
Department of Mechanical and Aerospace Engineering
University of Florida

April Groover Combs, Senior Management Analyst
Florida Department of Agriculture and Consumer Services, Office of Energy

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CHAPTER 1

1. EXECUTIVE SUMMARY

This is the Final Report of a project entitled “Mapping the Energy Landscape of Water and Wastewater Treatment Plants in the State of Florida.” The broad objective of the project was to establish a baseline on energy efficiency and renewable energy measures and practices at water and wastewater treatment plants (WWTPs) in Florida. The Florida Department of Agriculture and Consumer Services Office of Energy worked with the University of Florida Industrial Assessment Center (UF-IAC) which is housed in the Department of Mechanical and Aerospace Engineering at the University of Florida to complete this report.

One of the rationales for establishing a baseline on energy efficiency and renewable energy measures at WWTPs in Florida is to create a vehicle through which existing WWTPs can be benchmarked. The mechanics of establishing the baseline involved collecting key data from a sample of WWTPs. As a starting point, a sample of 121 WWTPs was carefully selected to include both industrial and domestic plants, with their capacities selected to be representative of existing plants in Florida. These plants were selected from a Florida Department of Environmental Protection (FDEP) database of over 5,000 domestic and industrial WWTPs. For purposes of the data collection process, an electronic energy survey was prepared and sent to all 121 WWTPs. Out of that number, 101 were classified as domestic and 20 were classified as industrial. Those contacted were given the option of either filling out an electronic survey or agreeing to have a one-day energy audit performed by the UF-IAC. The plants contacted were selected to be as representative as possible to the landscape in the categories of size and application (e.g. domestic vs. industrial). In the end, however, a total of ten WWTPs participated through the energy audit option. While the number of participating plants ended up being far less than the original sample of 121 facilities, the markedly varying sizes and processing capacities of the ten plants enabled us to categorize them into three representative size groups that turned out to be sufficient to give us some good insight into the operation of these plants. Thus, we believe we were able to capture the essence of what typically happens in WWTPs and consequently being reasonably successful in inferring some generalizations that can be applicable to a larger sample.

Table 1 on the following page shows the WWTPs that participated in the energy audits. They are organized into three groups according to their designed processing capacity. The acronyms in the table (WWTP, WWRF, WRF, WERF, WWT, etc.) are the official FDEP designations. As will be shown later in the report, about half the plants audited meet their design capacity.

Table 1. Participating Water and Wastewater Treatment Plants

GROUP	PLANT	CITY
I	OCU - WWTP	Orlando
	Buckman WWTP	Jacksonville
	Southwest WWRF	Jacksonville
II	Arlington East WRF	Jacksonville
	GRU WWTP	Gainesville
	W.E. Dunn WERF	Palm Harbor
	South Cross Bayou WWT	St. Petersburg
III	Lakeland WWT	Lakeland
	JEA W/WW & Reuse Plant	Jacksonville
	Thomas P. Smith WRF	Tallahassee

The facilities were incentivized to participate in the study by offering them a free analysis of their data if they opted to participate by filling out the survey or by being the recipient of a one-day free energy audit performed by the UF-IAC. The UF-IAC energy audit typically consists of a one-day site visit to the plant by a team of faculty and graduate engineering students. During the visit, the different processes are examined, and potential assessment recommendations (ARs) are sought out by the team. For the facilities selected for audits, a small number of them provided their energy bills and quantities of wastewater treated ahead of the appointed day of the audit. In those cases, a preliminary baseline analysis was carried out and discussed with the plant management.

The main goal of the audits was to help the plants reduce their energy usage, improve their productivity, and reduce and/or better manage any generated waste. At the end of the visit, potential ARs (20-22 on average) were discussed with the plant management which selected the ARs that they wanted the UF-IAC team to evaluate. The ARs selected by the plant management were the ones of most interest to them and thus had the highest likelihood of being implemented. Budget considerations were accounted for in the decision-making process. After the visit, the ARs were evaluated further and presented in the audit report based on a simple payback analysis. Typical metrics used in the AR selection process were a relatively short pay-back period (3 years or less) and/or a high strategic value to the plant. The number of ARs that were included in the audit report was in the vicinity of seven ARs.

After sixty days from the day of the site visit, an audit report was produced and sent for a critical review to the Field Manager of the Industrial Assessment Center Program. The Field Manager acts as technical arm of the Office of Energy Efficiency and Renewable Energy of the US Department of Energy which administers the Industrial Assessment Center Program. Once approved, the audit report was emailed to the plant management for implementation. After nine months from the site visit, a follow-up with the plant management is done in order to assess how many of the proposed ARs have been or will be implemented, and an implementation report reflecting the results of the follow-up process is uploaded to a database administered by the Field Manager for the US Department of Energy.

The typical implementation rate for the UF-IAC is about 20 percent of the estimated energy savings. At the time of this report, only one plant (UF0511) has implemented some of the ARs that we recommended. For this particular plant, management wanted to stay away from natural gas, hence the implementation of AR #1 for that plant was of highest interest. Specifically, they wanted to install a combined heat and power (CHP) system instead of a compressed natural gas (CNG) system. This particular recommendation matched a recommendation made by an energy service company (ESCO) that the plant hired prior to our audit to look into saving the plant energy.

In general, the audited plants are under no obligation to implement any of the recommended ARs. Nevertheless, they like to receive the audit report as it provides them with an advance assessment of what might work for their budget and their long-term operation and possible expansion. The US Department of Energy sets a rate of return of 20 percent or better as a good metric to target (with some exceptions allowed).

Best Practices

At the time of the site visit, we observe and document any and all best practices already implemented by the plant in the areas of management, operation, or maintenance. These are typical measures that help improve the plant's efficiency, profitability, or competitiveness. A summary of best practices observed in the WWTPs we audited as part of this study is provided in Chapter 6 of this report. Typically, some of these best practices may change, get modified, or are fine-tuned after the audit has been completed.

Assessment Recommendations

The recommendations made to the WWTPs included in this study cover areas such as:

- Motors
- Belts
- Pumps
- Aerators
- Blowers
- Lighting
- Compressed air
- Occupancy sensors
- Disinfection systems
- Boilers
- CHP systems
- Biogas
- Insulation
- Heat recovery
- Photovoltaic systems
- Power generators
- Nutrient recovery
- Energy management systems

Best practices pertaining to variable frequency drives (VFDs) are not listed above as they are included in the motors' recommendations.

Assessment Recommendations Savings

A summary of the overall cost savings, implementation cost, return on investment, electric and thermal energy savings, and the associated carbon dioxide reduction for all ten WWTPs studied are shown in Table 2. The largest capacity plants are included in Group I, whereas Group II contains intermediate-capacity plants, and Group III has the lower-capacity plants. A total of fifty assessment recommendations (ARs) were made to the ten WWTPs that were studied. We are hoping that the promising savings shown in

Table 2 for the ten plants studied would incentivize other plants in Florida to participate in future studies.

Table 2. Cost and Energy Savings for the Three Groups of WWTPs

	Cost Savings	**Implement-ation Cost**	**Simple Payback Period**	**Return on Investment**	**Electric Energy Savings**	**Thermal Energy Savings**	**CO_2 Reduction**
GROUP	**($/yr)**	**($)**	**(yrs)**	**(%/yr)**	**(kWh/yr)**	**(MMBtu/yr)**	**(tons CO_2/yr)**
I	2,199,991	6,973,813	3.17	31.55	20,454,658	146,290.0	1838.6
II	6,938,084	639,958	0.09	1,084.15	2,574,181	82,593.5	1369.9
III	829,404	1,953,407	2.36	42.46	3,734,988	145,611.0	3146.0
Total	**9,967,479**	**9,567,178**	**0.96**	**104.18**	**26,763,827**	**374,494.5**	**6,354.5**

Total annual cost savings of all plants is about $9,967,479

This represents a plant average of $996,748/yr in savings

Total reduction in energy consumption per plant is about 17.5 percent

Equipment List and Energy Balance:

To help see where energy is being used in the different plants, we refer to the energy equipment list and energy balance for each WWTP studied. This is an estimate based on the inventory of equipment that use electric energy in the plants and on the information provided during the audits. The estimate is an approximation because measurements of the most energy intensive equipment were not taken. For each plant, the energy balance is calculated by comparing our estimates on energy usage with the actual annual electric energy bills. In all cases, the deviation of the energy balances has been kept to below 2 percent. The equipment lists and energy balances for all plants studied are summarized in Chapter 7 of this report.

CHAPTER 2

2. GENERAL BACKGROUND

This chapter provides an overview of the water and wastewater treatment plants (WWTPs) that participated in the energy audits. It also provides a brief description of their processes, specialized energy requirements for those processes, and the associated products generated.

2.1 Brief Description of WWTPs Surveyed

The plants included in this report are ten water and wastewater treatment plants (WWTPs) located in Florida. They all receive wastewater from the respective areas they serve, process the wastewater, and then transfer the reclaimed water into spray fields, rivers, or local consumption. The plants are categorized as parts of Groups I, II, or III based on the design capacities of the water they can process and whether they treat the remaining sludge they generate. Some of these plants also produce biogas and bio-solids as secondary byproducts. The biogas is typically used in boilers inside the plants, and the rest is flared. The bio-fertilizer is typically palletized and sold or given to local farmers.

Most of the plants have been in operation for many years, with the oldest one being in operation for 52 years. In the State of Florida there are about 5000 WWTPs. They reclaim and process domestic and/or industrial wastewater with a pretty wide range of capacities. The number of employees in the WWTPs studied varied from a low of 20 to a high of 55 employees. The selection of 121 plants for the initial survey was based on recommendations by the Florida Office of Energy in the hope that we could capture an accurate picture of the operation of WWTPs in Florida. As stated in the previous chapter, they were selected in such a way so as to get a representative sample of such plants in Florida. Savings produced as a result of implementing the recommended ARs are typically used to increase the profit margin of the plant and/or to allow for plant expansion and possibly enable hiring more employees, thus helping overall the employment picture in Florida.

2.2 Classification of the WWTPs Surveyed

Table 3 shows the size and type of WWTPs that participated in the study in terms of their rated capacity in millions of gallons per day (MG) along with their National Pollutant Discharge Elimination System (NPDES) code. The NPDES is administered by the US Environmental Protection Agency (EPA). For more details see: www.epa.gov/npdes. The code listed corresponds to the one for WWTPs Plants that generate or not generate biogas (see the following link: www.resourcerecoverydata.org/biogasdata.php). As mentioned earlier, the plants have been separated in three groups. Group I has a rated capacity of 30 MG or higher, while Group II has a rated capacity between 10 and 30 MG. Finally, Group III has a rated capacity of 10 MG or lower.

Table 3. Participating Water and Wastewater Treatment Plants

Group	Report Number	Plant	City	Capacity (MG)	NPDES
I	UF0548	Buckman WWTP	Jacksonville	52.5	FL0026000
	UF0549	OCU - WWTP	Orlando	43.0	FLA107972
	UF0540	South Cross Bayou WWT	St. Petersburg	33.0	FL0040436
II	UF0511	Thomas P. Smith WRF	Tallahassee	26.5	FL0174441
	UF0545	Arlington East WRF	Jacksonville	15.0	FL0026441
	UF0547	Southwest WWRF	Jacksonville	14.5	FL0026468
	UF0535	Lakeland WWT	Lakeland	13.7	FL0039772
III	UF0544	GRU WWTP	Gainesville	10.0	FL0112895
	UF0542	W.E. Dunn WERF	Palm Harbor	9.0	FL0128775
	UF0533	JEA W/WW & Reuse Plant	Jacksonville	7.5	FL0023493

2.3 Energy Background of WWTPs Surveyed

The WWTPs audited use both electricity and natural gas for production and operational purposes. They are provided their energy by several Florida utility companies. Electric energy companies include Duke Energy, Jacksonville Electric Authority (JEA), Tampa Electric Company (TECO), Lakeland Electric Company, Gainesville Regional Utility (GRU), and Orlando Utilities Commission (OUC). Natural gas companies for nine of the ten WWTPs audited include Peoples Gas, Infinite, and Interconn. One WWTP uses propane in relatively small quantities. None of the WWTPs audited has ever undergone an energy audit in prior years. Generally, the UF-IAC typically coordinates its audits with the utility companies serving the plants to be audited.

2.4 Layout of the WWTPs Surveyed

The WWTPs audited are located in North Central Florida. Typically, the plant is divided in different sections which include office areas, water treatment areas, and solid treatment areas. The water treatment section separates solid from wastewater and treats water further. Some plants dispose of solids by sending the sludge to another plant, while others treat the sludge further and generate biogas. For the latter plants, the remaining sludge is treated to generate a bio-fertilizer that is sent out for use by the farmers.

The total area of the plant depends on the plant capacity. Typically, the size is in the order of tens of acres, including all buildings, and most of the operations happen outdoors. The facilities are in general comprised of the processing area, the pool area for storage, and the buildings area. Typically, there are HVAC systems that are used for air conditioning the office spaces and the electric control rooms. Major process equipment are the major electric and thermal energy consumers. Boilers and dryers are used by those plants that generate biogas and further treat the sludge and dry it. Some plants use a dewatering process instead of drying. Typical equipment includes the following:

- Motors
- Pumps
- Blowers
- Lighting

- Air compressors
- HVAC
- Boilers
- Dryers

A complete list of the electric equipment and an energy balance for each of the WWTPs studied are included in the individual audit reports generated for each plant.

2.5 Operating Schedule

The process operation at all the plants is continuous and runs throughout the year in three shifts, but the offices have a five-day week. Table 4 shows the approximate operating schedule in the plants studied throughout the year. In general, Supervisory Control and Data Acquisition (SCADA) systems provide just in time data for process monitoring and control. After the ARs have been implemented, a SCADA system can show the improvements in system operation due to the implementation of the ARS. Changes can be seen as soon as recommendations related to process modifications have been implemented. In some of the audited plants, in addition to a SCADA system, we have also recommended the installation of an Energy Management System (EMS). This is typically a software that controls illumination and HVAC systems at the same time. It typically is equipped with a monitor that can be installed next to the SCADA system monitor. Between the two systems, changes in energy consumption can be displayed in real time in a central control room at the plant.

Table 4. Facilities Typical Operating Hours

OPERATING SCHEDULE			
Area	**Shift**	**Days/week**	**Total hr/year**
Offices	7:00 am – 3:30 pm	5	**2,210**
Process	(1) 7:00 am – 3:00 pm (2) 3:00 pm - 11:00 pm (3) 11:00 pm – 7:00 am	7 7 7 **Total:**	**2,912** **2,912** **2,912** **8,760**

2.6 General Process Description

The three groups of WWTPs audited follow a similar process. In Figure 1 below, the processes are summarized from the perspectives of energy use and generation. As can be seen, the site boundary in the figure shows what sources of energy come into the plants, the products generated, and the byproducts produced. In the plants considered, the main source of energy for all the plants is electricity, with some using natural gas as well. A few were found to use a small amount of propane and diesel to run their back-up generators. Naturally, the product produced is reclaimed water. In addition, all of the plants produce sludge which, when treated, produces biogas and bio-fertilizer. This is accomplished either onsite at the plant itself or offsite through other companies.

In these plants, the onsite generated biogas can be used to run generators, boilers, a combined heat and power (CHP) system, or further treat the biogas to produce compressed natural gas (CNG). Furthermore, there is the possibility of site-generated power through renewable energy sources via the use of a photovoltaic (PV) system.

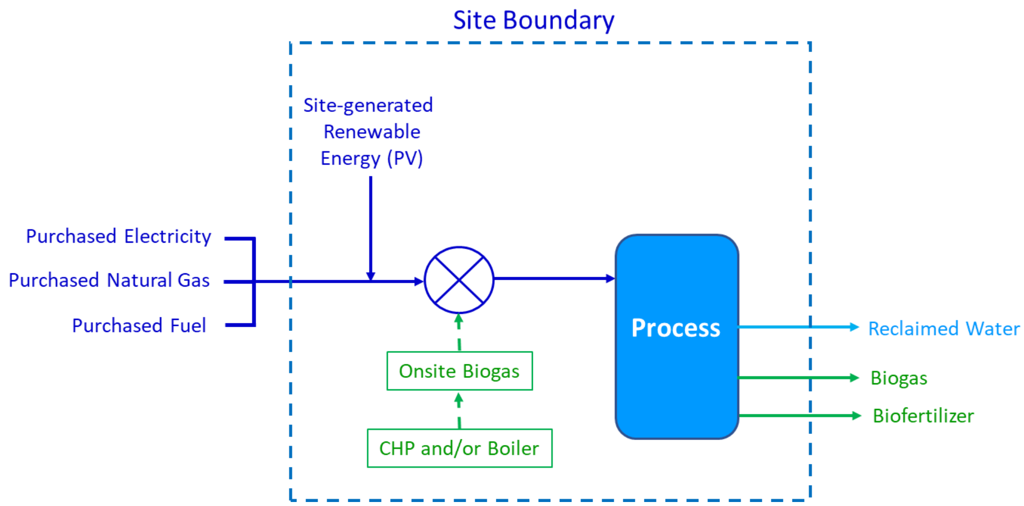


Figure 1. Energy use and generation in a WWTP

2.7 Detailed Process Description

The wastewater treatment process performed at the WWTPs studied is described to some degree of detail in this section. This treatment process consists of three steps plus a fourth step pertaining to handling of the solids produced.

2.7.1 Influent pumping station

Pump stations in the collection area transport wastewater through lines (some plants use gravity) to the influent pumping station. The influent pumping station consists of grinders followed by large pumps. One side receives wastewater from the city, and the other side receives wastewater from the service area.

2.7.2 Headworks

During the preliminary treatment, the incoming raw sewage, or influent, is strained to remove all large objects that make their way into the sewer system. These objects can be anything from rags and sticks to toys, cans and even snakes. The grinders protect the pumps by pulverizing all of the debris that comes their way. This preliminary treatment is done at the grit screening area. It consists of coarse screening, grit removal, and odor mitigation stages. The odor mitigation is done by bleaching the exhaust/vent air to remove any hydrogen sulfide gas present in the vent gas. The influent flows across coarse screens, and the objects trapped on the screens are raised out of the water and are then automatically raked off the screens. The sand, grit, and stones which are courser in size stick to the screen. The grit is removed from the channel, added to the larger objects removed by the bar screens, and taken to the landfill for disposal. Preliminary treatment is vital for preventing damage to pumps and other equipment in the remaining treatment stages.

2.7.3 Grit removal
The removal of smaller grit, sand or inorganic material is done by tangentially supplying the influent at a controlled velocity. The flow induces a vortex formation through a centrifugal force exerted by the side walls. The vortex forces the heavier material to the outer perimeter. Once they reach the outer perimeter they are pulled down by gravitational force. The influent with lighter particles moves out from the top to preliminary treatment. Heavier particles exit the bottom and go to the same grit system where they are compacted and sent to landfills.

2.7.4 Primary clarifiers
The primary treatment consists of primary sedimentation tanks commonly called primary clarifiers. The tanks are large enough that sludge can settle and floating materials such as grease and oils can rise to the surface and be skimmed off. The main purpose of the primary treatment is to produce both a generally homogeneous liquid capable of being treated biologically and a sludge that can be separately treated or processed. Primary clarifiers are equipped with mechanically-driven scrapers that continually drive the collected sludge towards a hopper in the base of the tank from where it can be pumped to further sludge treatment stages. The clarified water flows on to the next step of the treatment process.

2.7.5 Biological nutrients removal
This consists of three Biological Nutrients Removal (BNR) anoxic tanks where anaerobic bacteria breaks down the nutrient. BNR basins include a four-stage nitrogen removal process that comprises anoxic, swing, aerobic and second anoxic zones. During this process, the microbial growth is suspended in an aerated water mixture where the air is pumped in, or the water is agitated sufficiently to allow oxygen transfer. The suspended growth process speeds up the work of aerobic bacteria and other microorganisms that break down the organic matter in the sewage by providing a rich aerobic environment where microorganisms suspended in the wastewater can work more efficiently. In the aeration tank, wastewater is vigorously mixed with both air and microorganisms acclimated to the wastewater in suspension for several hours. This allows bacteria and other microorganisms to break down the organic matter in the wastewater.

2.7.6 Secondary clarifiers
After biological treatment, the water is pumped to secondary clarifiers where any leftover solids along with the microorganisms sink to the bottom.

2.7.7 Mixing tank and secondary treatment
This is comprised of a fast mixing station used to add chemicals to the effluent from the aeration tanks and then send them to secondary clarifiers. The secondary clarifiers facilitate settling of the sludge particles and microorganisms, and further clarify the water. There is a vacuum arm slowly rotating around the bottom to scrape off the sludge and return the microorganisms to the anoxic tanks.

2.7.8 Denitrification filters
The nitrogen compounds from the water are to be removed before the latter is discharged to rivers, creeks, or other bodies. Excess nitrogen accelerates growth of algae and plants. To reduce this effect, methanol is added to wastewater and then wastewater is sent to sand

filters. Bacteria in the sand break down the nitrates and turn them into nitrogen that goes to the atmosphere. It also acts as a filter for suspended solids.

2.7.9 Disinfection

The filtered water is treated with either chlorine or passing it through a set of ultraviolet (UV) lamps to disinfect and remove the bacteria that are present due to the previous treatment stages. The water sent to local housing is chlorinated, while water sent to lakes, rivers or creaks is UV disinfected as the chlorine traces are not allowed in creeks because of environmental rules. After disinfection, water is sent to storage tanks or holding ponds from where it is pumped to local water bodies. If chlorinated water is in excess of the available storage capacity and needs to be sent to a creek, then it is de-chlorinated using SO_2 gas.

2.7.10 Solids handling

All three groups of WWTPs treat sludge in a similar manner, as it comes from both the primary and secondary clarifiers. The sludge from the nitration process is sent to a rotating drum thickener where most of the water is removed, and a special polymer is added to further thicken the sludge. The thickened sludge is then sent to the biodigesters. The bacteria present in the sludge breaks down the organic matter under anaerobic conditions and produces methane. This process increases the nitrogen concentration in the sludge making it a more effective fertilizer. The treated sludge from the biodigester is then sent to a storage tank next to it. When the storage capacity is reached the sludge is sent to the pelletizer unit for further processing.

2.7.11 Pelletizer

The received sludge is dewatered using a centrifuge system. Polymer is added to get the sludge at a specific viscosity. Some plants send this mixture to a glass furnace to remove all the water and form tiny pellet shaped fertilizer granules. These in turn go through sizing screens where the larger pellets are removed and crushed. The pellets are then sent to silos for storage. These silos are connected to the loading area where trucks are loaded, and the fertilizer pellets are sold to specific vendors.

2.8 Process Flow Charts

As indicated before, the wastewater treatment processes are very similar among the three groups of WWTPs studied. The variations among them are mostly due to the existence or lack thereof of a BNR treatment process between the primary and secondary clarifiers, the type of the disinfection process through either a UV-lamp system or a chlorination process, and the further treatment of the sludge in case there is interest or need in producing biogas and/or biofertilizer. Figures 2, 3, and 4 show the wastewater treatment process at the three groups of WWTPs studied, including the solid treatment processes.

GROUP I

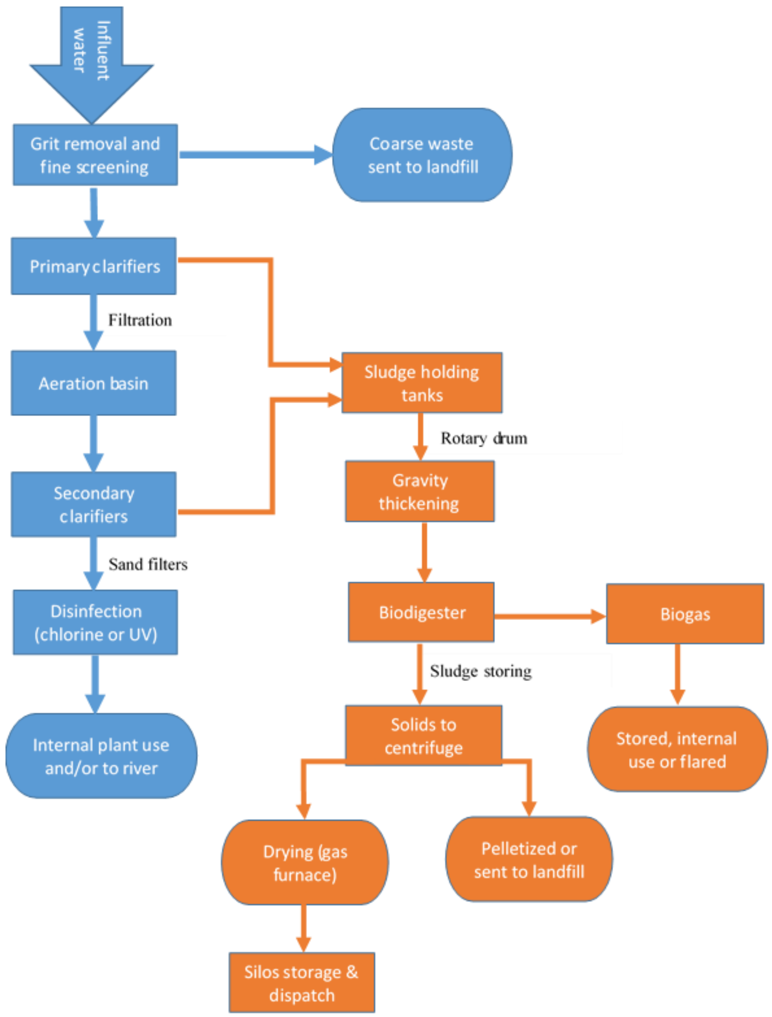


Figure 2. Flowchart of wastewater treatment for WWTPs in Group I

GROUP II

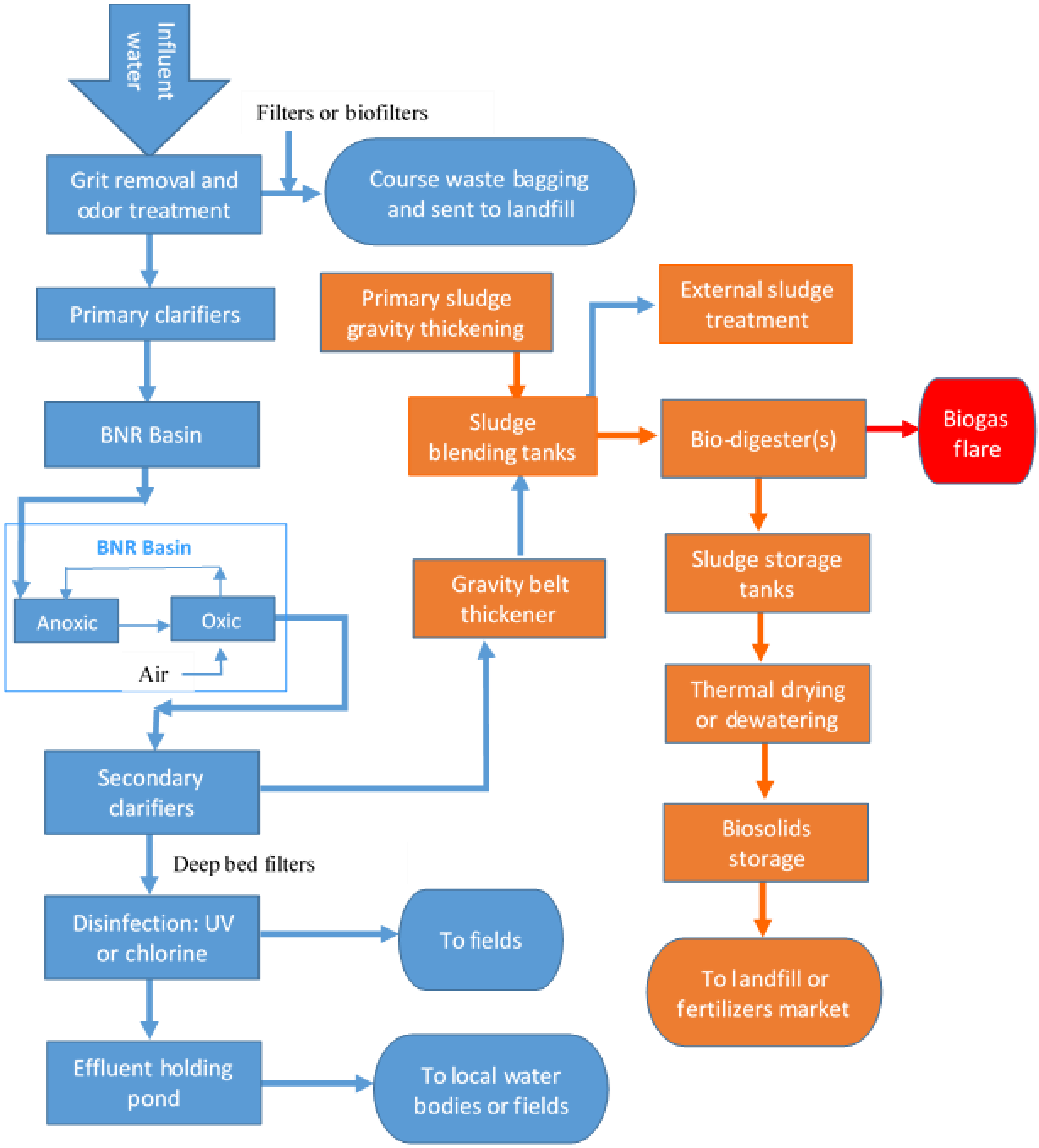


Figure 3. Flowchart of wastewater treatment for WWTPs in Group II

GROUP III

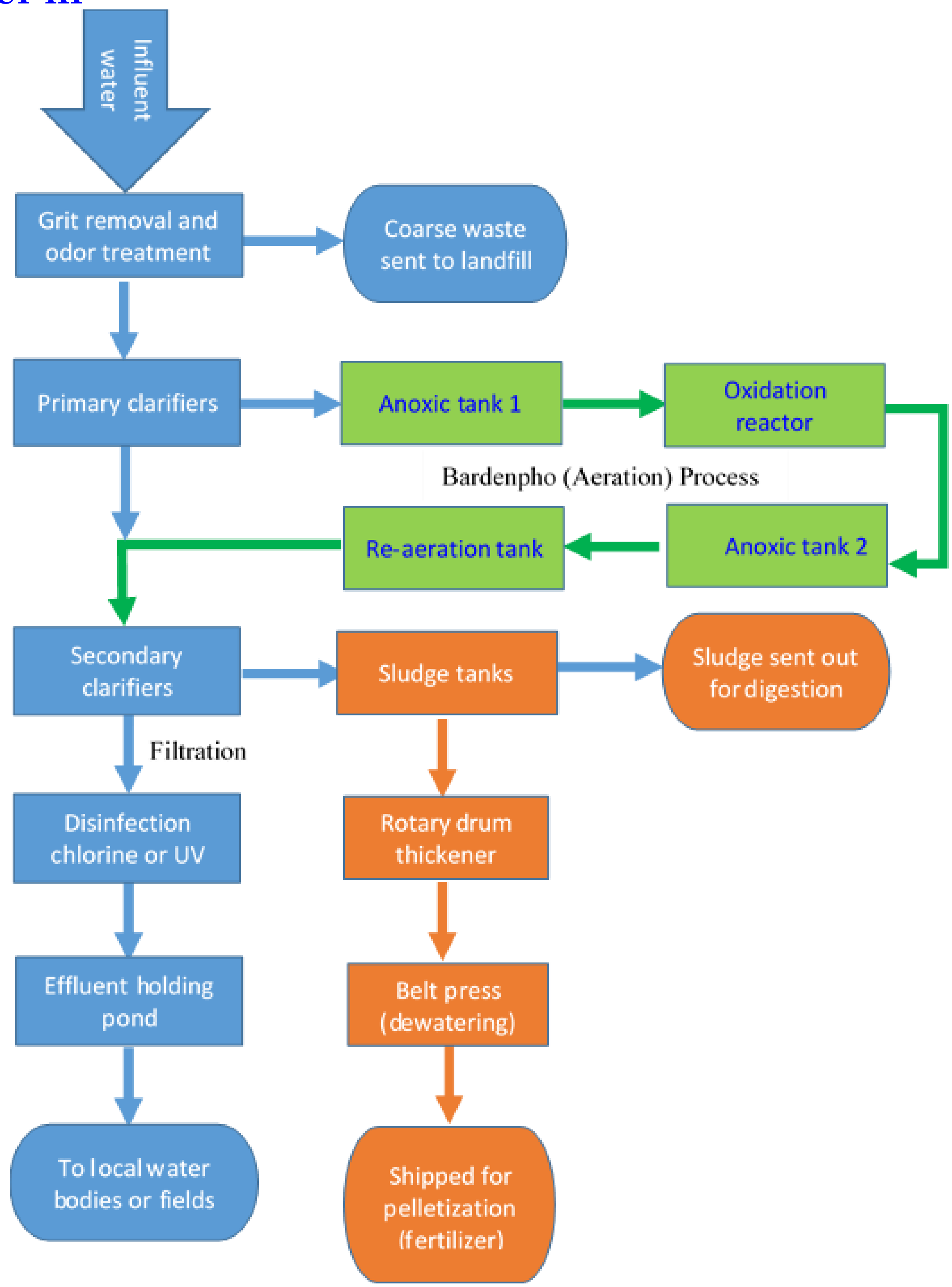


Figure 4. Flowchart of wastewater treatment for WWTPs in Group III.

2.9 Facility Material and Waste Chart

Table 5 gives the waste generated in the facilities and the method of disposal.

Table 5. Waste Generated and its Disposal

Raw Material	Waste Generated Type	Method of Disposal
Wastewater	Sub-standard bio-solid, grit, rugs, plastic, stones, etc.	Landfilled

CHAPTER 3

3. FACILITIES SURVEYED BY CAPACITY AND ENERGY USE

The WWTPs audited are listed in Table 6 below. They are rated in terms of their capacity in millions of gallons per day (MG), energy use, energy cost and their national pollutant discharge elimination system (NPDES) code. Accordingly, they have been separated in three groups as discussed earlier. Group I have a rated capacity of 30 MG or higher. Group II has a rated capacity between 10 and 30 MG. Group III has a rated capacity of 10 MG or lower.

Table 6. WWTPs Surveyed Showing Location, Rated Capacities, Energy Use, and NPDES Codes

Group	Report Number	Plant	City	Rated Capacity (MG)	Energy Use			NPDES
					Electricity (kWh/yr)	Natural Gas (MMBtu/yr)	Total Cost ($/yr)	
I	UF0548	Buckman WWTP	Jacksonville	52.5	35,968,031	180,264	2,801,370	FL0026000
	UF0549	OCU - WWTP	Orlando	43.0	42,058,447	8,597	3,341,329	FLA107972
	UF0540	South Cross Bayou WWT	St. Petersburg	33.0	28,473,059	69,228	2,043,107	FL0040436
II	UF0511	Thomas P. Smith WRF	Tallahassee	26.5	18,074,400	60,667	1,882,490	FL0174441
	UF0545	Arlington East WRF	Jacksonville	15.0	16,988,917	-	1,063,061	FL0026441
	UF0547	Southwest WWRF	Jacksonville	14.5	7,882,844	-	496,619	FL0026468
	UF0535	Lakeland WWT	Lakeland	13.7	7,077,600	1,039	510,003	FL0039772
III	UF0544	GRU WWTP	Gainesville	10.0	12,320,400	-	1,359,812	FL0112895
	UF0542	W.E. Dunn WERF	Palm Harbor	9.0	6,848,676	-	547,730	FL0128775
	UF0533	JEA W/WW & Reuse Plant	Jacksonville	7.5	9,891,135	-	620,750	FL0023493

Note that the associated cost of energy has not been used to compare the facilities. The reason is that different facilities typically have different electric and natural gas utility companies and hence different tariffs. As the tariffs or rates vary between the utilities, the comparison would not be based on the same unit cost of energy and would therefore skew the readers interpretation of energy expenditures.

3.1 Comparison of Capacity of the WWTPs with Energy Usage

From Table 6 we can create a new table (Table 7) showing each WWTP's daily rated capacity in million gallons (MG), the annual rated capacity in million gallons per year (MG/yr), the total annual energy usage in million British thermal units per year (MMBtu/yr), the total annual electricity usage in kWh/yr, and the total annual natural gas usage in MMBtu/yr. Please note that total annual energy usage is the sum of the total annual electricity usage and the total annual natural gas usage after converting the kWh/yr into its energy equivalent in MMBtu/yr. To do the conversion, we utilized the conversion factor of one kWh being equivalent to 0.003412MMBtu.

Table 7. Rated Capacities, Amount of Treated Wastewater, and Energy Use

Group	Report Number	Rated Capacity (MG)	Rated Capacity (MG/yr)	Wastewater Treated (MG/yr)	Total Energy (MMBtu/yr)	Electricity (kWh/yr)	Natural Gas (MMBtu/yr)
I	UF0548	52.5	19,162.5	8,860.8	302,986.9	35,968,031	180,264
	UF0549	43	15,695.0	14,391.0	152,100.4	42,058,447	8,597
	UF0540	33	12,045.0	8,206.3	166,378.1	28,473,059	69,228
II	UF0511	26.5	9,672.5	6,524.7	122,336.9	18,074,400	60,667
	UF0545	15	5,475.0	7,439.7	57,966.2	16,988,917	0
	UF0547	14.5	5,292.5	4,080.8	26,896.3	7,882,844	0
	UF0535	13.7	5,000.5	3,142.0	25,187.8	7,077,600	1,039
III	UF0544	10	3,650.0	3,472.6	42,037.2	12,320,400	0
	UF0542	9	3,285.0	2,415.6	23,367.7	6,848,676	0
	UF0533	7.5	2,737.5	2,659.5	33,748.6	9,891,135	0

With this table, we carried out an analysis of the rated capacity versus the wastewater treated. Seven different linear regression plots were constructed (as will be discussed shortly). The best performance is represented by any point on the regression line. Data points above the regression line use more energy while data points below it uses less energy.

3.2 Rated Capacity versus Wastewater Treated

Figure 5 displays the rated capacity of the plants and the volume of wastewater they treat for all three groups of WWTPs. Except for Plant UF0545, all other plants were found to treat less wastewater than their rated capacities (see Figure 5).

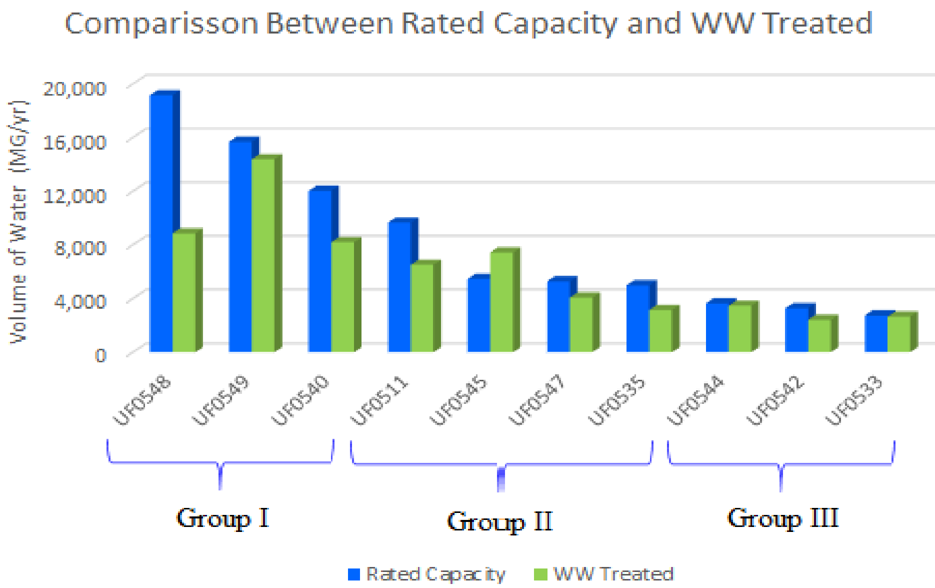


Figure 5. Comparison between the WWTPs' rated capacity and the wastewater they treat

3.3 Total Energy Use versus Rated Capacity

Figure 6 on the following page shows a very good linear correlation (correlation coefficient 90.77 percent) between the rated capacity of the plants and their total energy usage. The slope of the line represents the amount of energy in MMBtu required by the plants to treat 1 MG of wastewater per year. The slope of the line in this case is 15.207 MMBtu/MG. It represents the rate of increase of energy usage per 1 MG/yr of wastewater that can be treated. As can be seen, the more wastewater is treated the higher the amount of energy used, with the increase being almost linear. While the increase is expected, the linear relationship is an indication of the fact that no obvious energy savings can be realized by simply treating large amounts of wastewater. In other words, there is no obvious advantage in treating large amounts of wastewater on a per-unit-basis of energy consumed.

Please note that the above correlation considers the designed or rated capacity (as opposed to the actual capacity) of the plants with the energy usage. Some plants (e.g. UF0548) are supplied with sludge from other plants that neither use natural gas nor treat the sludge they produce. Consequently, in the sections that follow the surveyed facilities will be compared based on the actual annual amount of wastewater they treat (as opposed to their rated or design capacities) versus the energy they use.

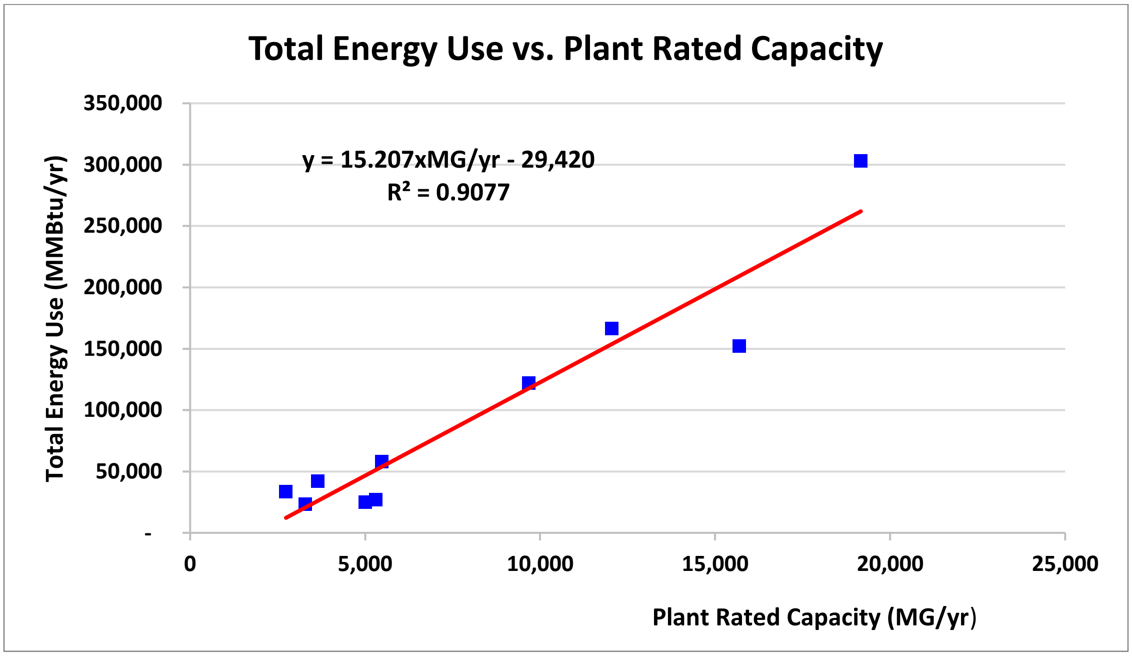


Figure 6. Total energy use versus plant rated capacity

3.4 Total Energy Use versus Wastewater Treated

Figure 7 displays the relationship between the total energy use and the actual amount of wastewater treated. As can be seen, the figure shows a relatively low linear correlation (correlation coefficient 46.79 percent) between the total energy usage and the amount of wastewater treated. The slope of the line represents the amount of energy, in MMBtu, used by the plants to treat 1 MG of wastewater per year. The slope of the line in this case is 16.556 MMBtu/MG. It represents the rate of energy usage per 1 MG/yr of wastewater treated. As can be seen, the larger the amount of wastewater treated the larger the scatter of data points. Conversely, plants that treat smaller amounts of wastewater show a more linear correlation with the total energy used. The larger scatter in the data with larger amounts of wastewater treated is an indication that there is significant potential for large energy saving opportunities.

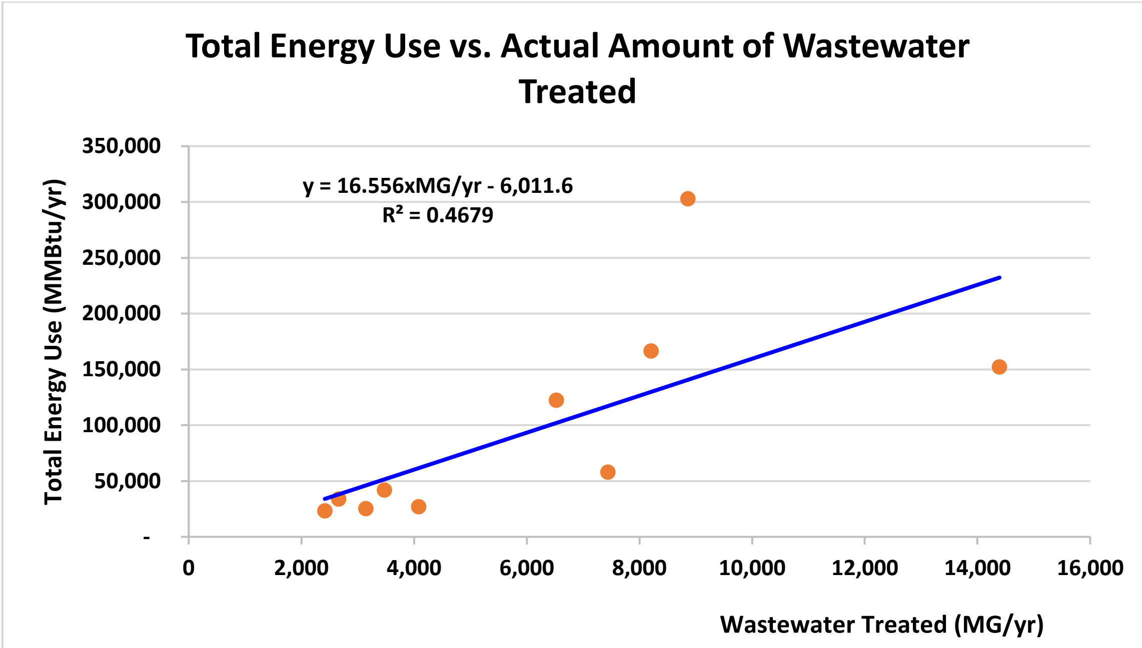


Figure 7. Total energy use versus actual amount of wastewater treated

3.5 Electric Energy Use versus Wastewater Treated for WWTPs Capable of using both Electricity and Natural Gas

Figure 8 on the following page displays the total electric energy use as a function of the actual amount of wastewater treated for facilities that have the capability to use both electricity and natural gas. In other words, while Figure 3 is focused on electric energy use data, the WWTPs from whose data this figure is generated have the capability to use both modes of energy. This is to be contrasted with electric energy data that will be presented and discussed in the following section that belong to facilities that do not have the capacity to use natural gas.

As can be seen in Figure 8, a good linear correlation (correlation coefficient 88.82 percent) exists between the electric energy usage and the amount of wastewater treated. The slope of the line represents the rate of increase of electric energy in kWh used by the plants to treat 1 MG of wastewater per year. The slope of the line in this case is 3,176.8 kWh/MG. It represents the rate of electric energy usage per 1 MG/yr of wastewater treated.

As can be seen, the larger the amount of wastewater treated the larger the amount of electric energy used, with the increase being almost linear. While the increase is expected, the linear relationship is an indication of the fact that no obvious energy savings on a per unit electric energy basis can be realized by simply treating large amounts of wastewater.

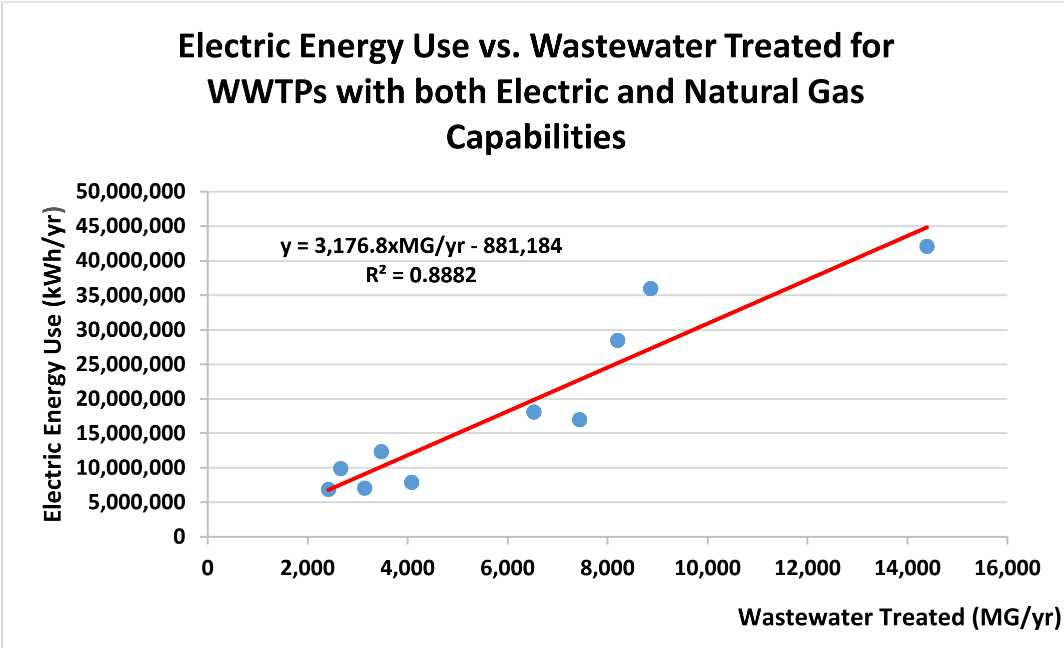


Figure 8. Electric energy use versus actual amount of wastewater treated for WWTPs capable of using both electric energy and natural gas

3.6 Electric Energy Use versus Wastewater Treated for Facilities with Electric-Only Energy

Figure 9 displays the total electric energy use in terms of the actual amount of wastewater treated for facilities that have electric energy only as the mode of energy to treat wastewater. As can be seen, a relatively good linear correlation (correlation coefficient 71.42 percent) exists between the electric energy used and the amount of wastewater treated. The linear correlation is good but not as good as those correlations of plants discussed in the previous two sections. There are five plants (UF0545, UF0547, UF0544, UF0542 and UF0533) that fall in the electric-only mode of energy usage category. The slope of the line in Figure 9 represents the amount of electric energy, in kWh, used by the plants to treat 1 MG of wastewater per year. The slope of the line in this particular case is 1,688.5 kWh/MG. It represents the rate of energy usage per 1 MG/yr of wastewater treated. As can be seen, the more wastewater treated the larger the scatter in the data points. Conversely, plants that treat smaller amounts of wastewater show a more linear correlation with electric energy usage.

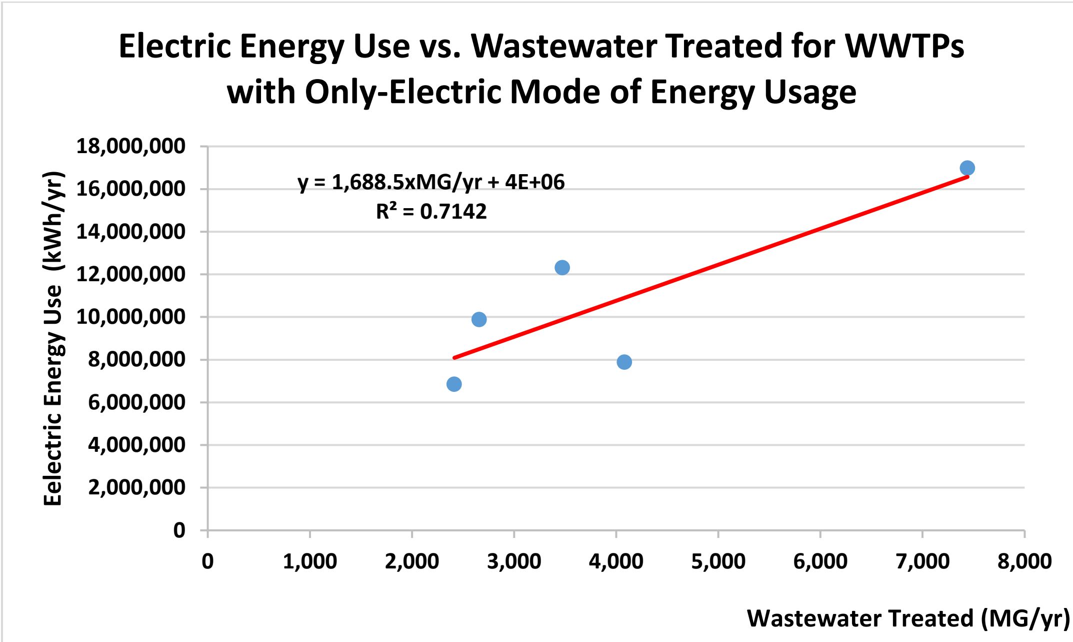


Figure 9. Electric energy use versus actual amount of wastewater treated for WWTPs capable of using electric energy only

3.7 Natural Gas Use versus Wastewater Treated

Figure 10 below displays natural gas energy usage as a function of the actual amount of wastewater treated for plants that have the capability of using both electricity and natural gas. This category of plants includes UF0548, UF0549, UF0540, UF0511, and UF0535. As can be seen, Figure 10 displays a very poor linear correlation of the data (correlation coefficient 0.24 percent). The slope of the line represents the amount of natural gas in MMBtu used by the plants to treat 1 MG of wastewater per year. The slope of the line in this particular case is 0.8623 MMBtu/MG. It represents the rate of energy usage per 1 MG/yr of wastewater treated.

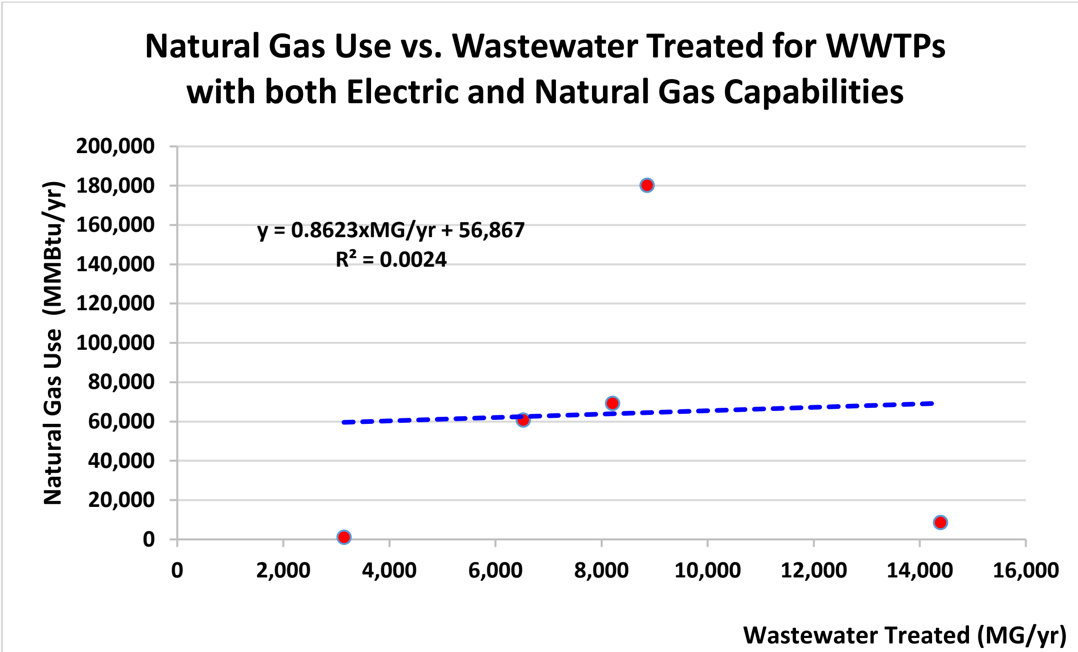


Figure 10. Natural gas use versus actual amount of wastewater treated for WWTPs capable of using both electricity and natural gas

3.8 Combined Electric and Natural Gas Use versus Wastewater Treated

Figure 11 displays the combined electric and natural gas energy usage as a function of the amount of wastewater treated. Naturally, the data points in this figure are for plants that have the capability of using either one of those two modes of energy. Thus, the plants whose data are presented in Figure 11 are those of UF0548, UF0549, UF0540, UF0511, and UF0535. Although the linear correlation of the data points is poor (correlation coefficient 23.35 percent), it is two orders of magnitude better than the linear correlation reported in the previous section for natural gas energy usage. The slope of the line represents the amount of combined energy (electricity and natural gas) in MMBtu used by the plants to treat 1 MG of wastewater per year. The slope of the line in this case is 11.785 MMBtu/MG. It represents the rate of combined energy usage per 1 MG/yr of wastewater treated. As can be seen, the larger the amount of wastewater treated the larger the scatter in the data points. Conversely, plants that treat smaller amounts of wastewater show a more linear correlation.

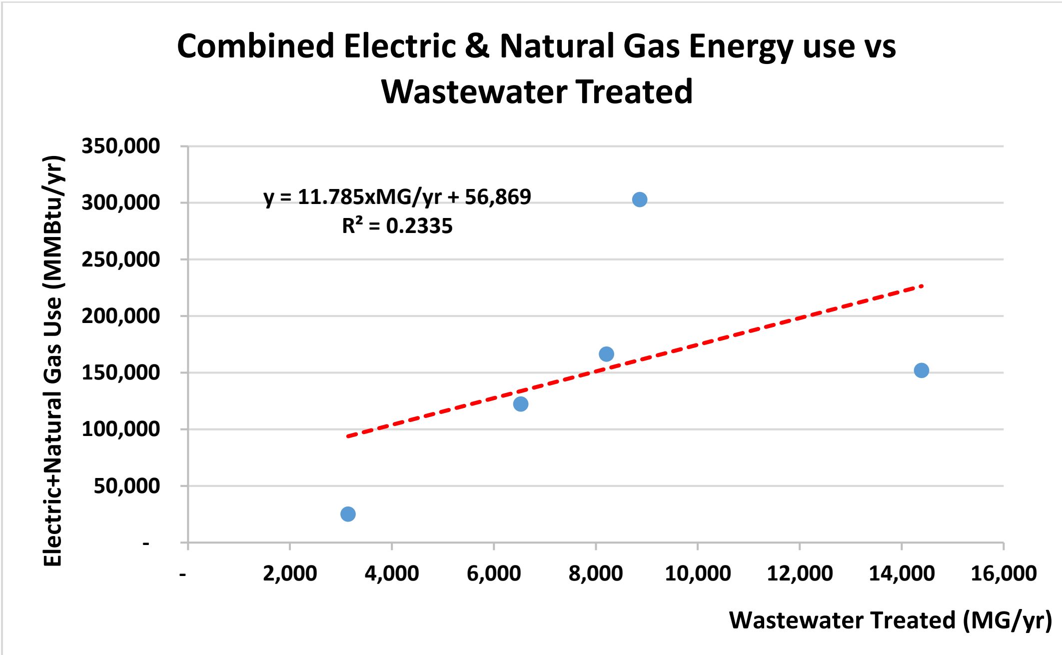


Figure 11. Combined electric and natural gas energy use versus volume of wastewater treated

CHAPTER 4

4. ENERGY ANALYSIS AND BASELINE

This chapter provides an analysis of the electric and thermal energy usages and their associated costs for the WWTPs surveyed. Some trends and irregularities in energy usage are discussed. This chapter also describes the relative merits of energy conservation and load management as they apply to the WWTPs surveyed.

4.1 Energy Use and Costs

The electric and natural gas energy use and costs of the ten WWTPs surveyed are listed in Table 8.

Table 8. Annual Electric, Thermal (Natural Gas) Energy Usage and Costs per Plant

Group	Report Number	Electricity (MMBtu/yr)	Natural Gas (MMBtu/yr)	Electricity Cost ($/yr)	Natural Gas Cost ($/yr)
I	UF0548	122,723	180,264	2,265,986	535,384
	UF0549	143,503	8,597	2,481,448	25,533
	UF0540	97,150	69,228	1,452,126	381,516
II	UF0511	61,670	60,667	372,333	572,454
	UF0545	57,966	0	1,061,807	-
	UF0547	26,896	0	496,619	-
	UF0535	24,149	1,039	389,268	42,659
III	UF0544	42,037	0	689,942	-
	UF0542	23,368	0	431,467	-
	UF0533	33,749	0	929,767	-

Figure 12 shows the total annual energy usage for both electricity and natural gas for each plant in MMBtu/yr. As mentioned before, the total annual energy usage is the sum of the total annual electricity usage and the total annual natural gas usage, after converting the kWh/yr into its energy equivalent in MMBtu/yr. As can be seen, Figure 12 shows higher energy usage in Group I, lower usage in Group II, and much lower usage in Group III. None of the plants showed any electric energy power factor charges (kVA or kVAR). Figure 13 shows the associated annual energy costs for all ten plants classified according to their respective group.

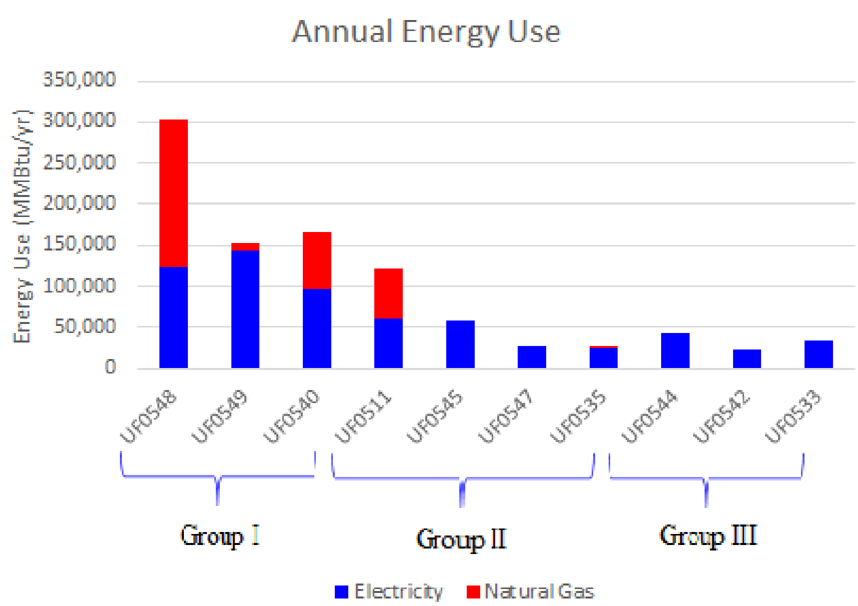


Figure 12. Annual energy use per plant for the three groups of WWTPs surveyed

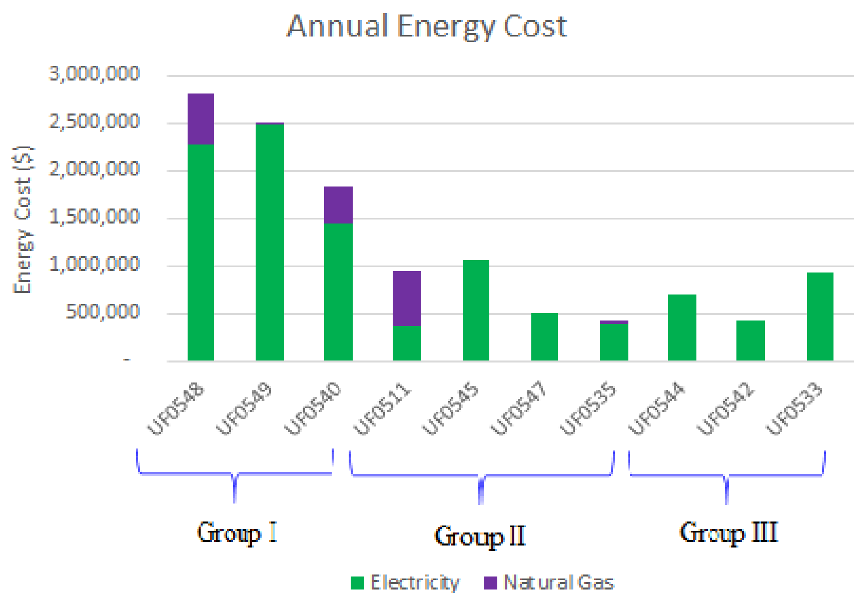


Figure 13. Annual energy cost per plant for the three groups of WWTPs surveyed

4.2 Energy Cost Comparison

The energy costs for both electricity and natural gas are not the same for most of the facilities since they have different utility companies. The energy cost is important because sometimes a piece of equipment could either run on electricity or on natural gas thus creating opportunities for energy savings if the more energy efficient choice is made.

To compare the costs of electricity ($/kWh) and natural gas ($/MMBtu), the electric energy cost is converted to $/MMBtu. The electric demand (kW) is reflected in the use of energy (and its cost) through the number of hours the electric power (demand) is used, and hence its energy component is used in the analysis. In addition, some tariffs are of the "energy-only" type, and thus no demand charges are present.

Furthermore, the cost of natural gas has been divided by 0.8 to account for the efficiency of the thermal equipment energy use. Table 9 shows the unit costs of electricity and natural gas for each plant. In the same table (far right), an "energy factor" is estimated as the fraction between electric energy and the thermal energy (both in $/MMBtu). This factor gives the multiplier between the cost of electricity and the cost of natural gas. For example, an energy factor of 4.97 means that using electricity would cost 4.97 times more than using natural gas. For plants in Group I, the thermal energy is cheaper than electric energy by a factor of 3.93. For Group II, only two plants use thermal energy, from which the factor has an average value of 0.41, meaning that, for these plants, electric energy is 41 percent cheaper than thermal energy. It must be pointed out that plant number UF0535 uses propane as a source of thermal energy, which is much more expensive than natural gas. The amount of biogas generated in some plants is also displayed in the form of its equivalence in electric power

(MW – estimated with plants personnel), which is not accounted for as no thermal energy is used by those plants.

Not all the plants use natural gas as shown in Tables 8 and 9. The reasons are essentially related to the fact that after the wastewater has been treated, the sludge is sent for further treatment to produce biogas to either a private company or to a sister plant (owned by the same company). In addition, the remaining sludge can generally be considered as potentially a good raw material to convert to a fertilizer. This typically depends on its remaining organic matter and its nitrogen, phosphate, and potassium content. During the site visit of the WWTPs, a small fraction of the biogas generated was used as a fuel in the boilers, whereas the greater fraction was either flared or burned in special torches. This was identified as an energy saving opportunity as will be shown in Chapter 7 of this report.

Table 9. Annual Electric and Thermal (Natural Gas) Energy Usage and Costs

Group	Report Number	Electric Demand		Electric Energy		Thermal Energy	Biogas	Energy Factor
		kW/month	($/kW-mo)	$/kWh	($/MMBtu)	($/MMBtu)	(MW)	
I	UF0548	11,824	-	0.063	18.46	3.71	3.0	**4.97**
	UF0549	7,541	8.316	0.059	17.29	3.71	2.5	**4.66**
	UF0540	8,024	5.899	0.051	14.95	6.89	2.0	**2.17**
II	UF0511	3,382	12.913	0.0206	6.04	11.80	2.0	**0.51**
	UF0545	3,016	-	0.0625	18.32	-	-	-
	UF0547	1,287	-	0.063	18.46	-	-	-
	UF0535	1,220	4.718	0.055	16.12	51.32	-	**0.31**
III	UF0544	1,836	9.750	0.094	27.55	-	-	-
	UF0542	2,865	5.504	0.056	16.41	-	-	-
	UF0533	2,835	-	0.063	18.46	-	-	-

4.3 Electric and Thermal Energy Use by Plant

In this section, the electric and natural gas (thermal) energies for all ten plants are examined within their respective groups and are plotted to highlight their differences. The data in Tables 10 and 11 were used to generate three bar charts corresponding to each table. The bar charts display the electric, natural gas, and total energy distributions for plants in Groups I and II, respectively. For Group III, only one bar chart was generated using the data in Table 12. The reason is the fact that electricity is the only energy source used in the plants of that group. The bar charts plotted from the data of Table 10 for the plants in Group I are shown in Figures 14, 15, and 16 for the electric, natural gas, and total energy use distributions, respectively. The bar charts plotted from the data of Table 11 for the plants in Group II are shown in Figures 17, 18, and 19 for the electric, natural gas, and total energy use distributions, respectively. The bar chart plotted from the data of Table 12 is shown in Figure 20 for the electric energy use distribution of the plants in Group III.

Bar Charts for Plants in Group I

The variations in energy usage along the year for the plants in this group are small and are primarily due to the different amounts of rain fall in the different months of the year. Some of the variations can also be attributed to seasonal tourism such as those plants in the Orlando area during the tourism season in Florida.

Table 10. Electric Energy and Natural Gas Use Distributions for Plants in Group I

	UF0548		UF049		UF0540	
	Electricity (kWh)	Natural Gas (MMBtu/yr)	Electricity (kWh)	Natural Gas (MMBtu/yr)	Electricity (kWh)	Natural Gas (MMBtu/yr)
Jan	3,018,781	15,022	3,661,694	859.4	2,529,967	7,446.3
Feb	3,261,074	15,022	3,415,908	961.1	2,212,957	5,456.6
Mar	2,943,591	15,022	3,156,706	781	2,160,184	5,641.0
Apr	2,976,071	15,022	3,320,611	761.3	2,374,596	6,976.3
May	3,118,083	15,022	3,595,527	782.4	2,287,178	7,343.0
Jun	3,232,582	15,022	3,450,362	617.3	2,269,995	4,881.1
Jul	2,736,782	15,022	3,847,922	676.7	2,556,769	4,808.3
Aug	3,067,054	15,022	3,565,622	531.9	2,338,866	5,235.0
Sep	2,899,634	15,022	3,719,292	786.9	2,431,255	5,387.8
Oct	2,781,669	15,022	3,501,365	604.5	2,391,694	4,879.3
Nov	2,826,798	15,022	3,568,872	540.8	2,488,863	4,431.2
Dec	3,105,912	15,022	3,254,566	693.6	2,430,735	6,758.6
Total Energy	5,968,031	180,264	42,058,447	8,596.9	28,473,059	69,244.5

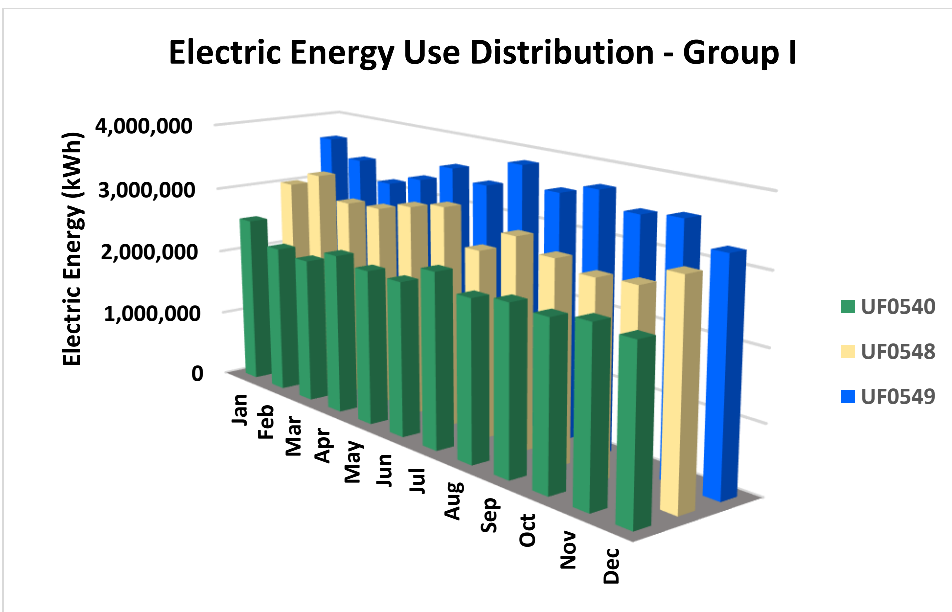


Figure 14. Electric energy use distributions for plants in Group I

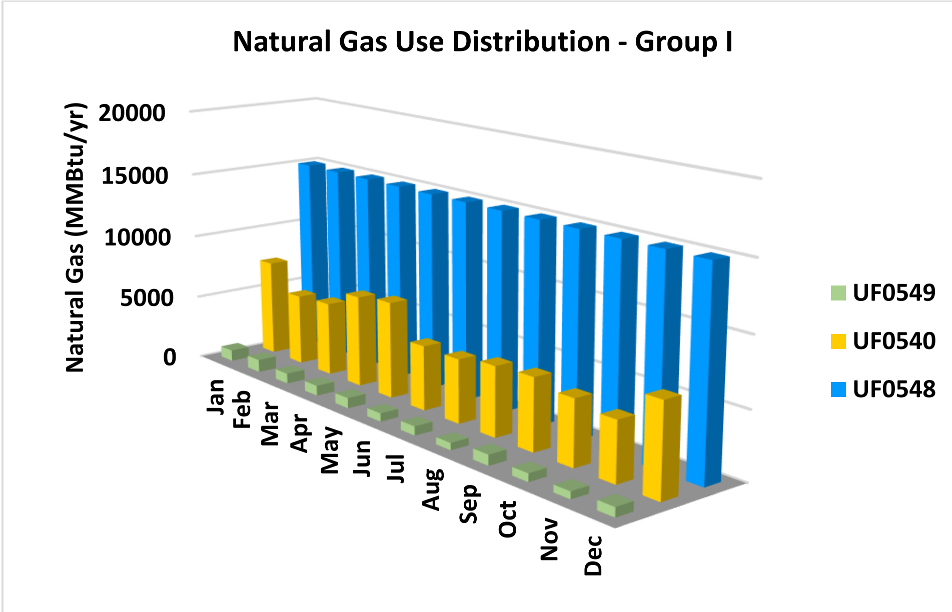


Figure 15. Natural gas energy use distributions for plants in Group I

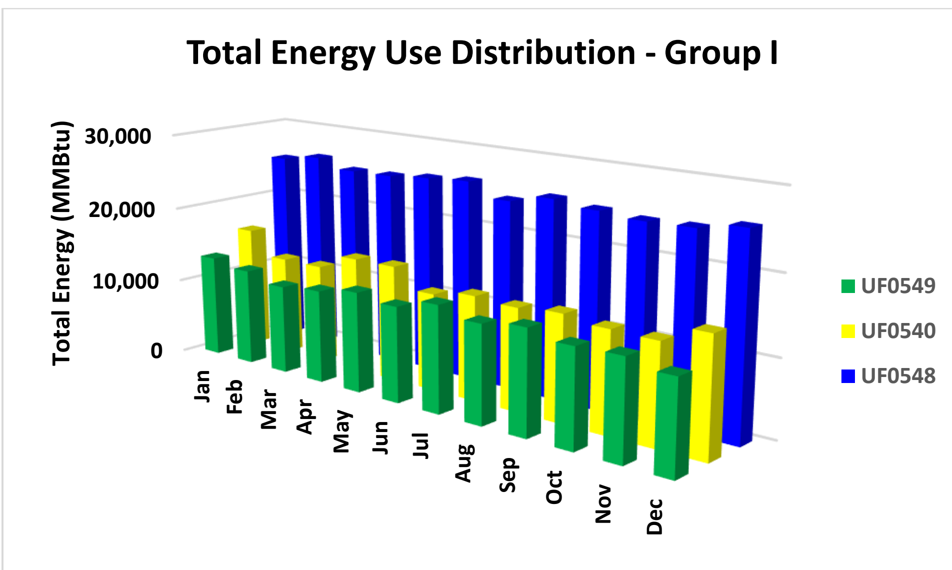


Figure 16. Total energy use distributions for plants in Group I

Bar Charts for Plants in Group II

As is the case with plants in Group I, plants in Group II also experience small seasonal variations in energy use due to rainfall and seasonal tourism.

Table 11. Electric Energy and Natural Gas Use Distributions for Plants in Group II

	UF0511		UF0545		UF0547		UF0535	
	Electricity (kWh)	Natural Gas (MMBtu/yr)	Electricity (kWh)	Natural Gas (MMBtu/yr)	Electricity (kWh)	Natural Gas (MMBtu/yr)	Electricity (kWh)	Propane Gas (MMBtu/yr)
Jan	1,620,000	5,112.8	1,313,502	-	648,655	-	526,800	261.28
Feb	1,399,200	6,343.2	1,526,028	-	681,680	-	550,800	166.33
Mar	1,428,000	3,642.2	1,313,031	-	645,894	-	622,800	132.08
Apr	1,473,600	6,760.4	1,339,514	-	658,945	-	580,800	33.52
May	1,663,200	5,828.1	1,484,211	-	720,982	-	558,000	49.13
Jun	1,492,800	4,713.6	1,397,331	-	605,726	-	633,600	84.99
Jul	1,593,600	4,002.6	1,393,771	-	620,136	-	655,200	39.66
Aug	1,497,600	3,754.8	1,621,500	-	685,850	-	640,800	91.99
Sep	1,576,800	4,712.3	1,416,136	-	568,917	-	633,600	37.68
Oct	1,632,000	5,581.8	1,521,388	-	611,754	-	603,600	41.53
Nov	1,332,000	5,250.7	1,364,089	-	697,375	-	585,600	51.59
Dec	1,365,600	4,964.2	1,298,416	-	736,930	-	486,000	49.16
Total Energy	18,074,400	60,666.8	16,988,917	-	7,882,844	-	7,077,600	1,038.9

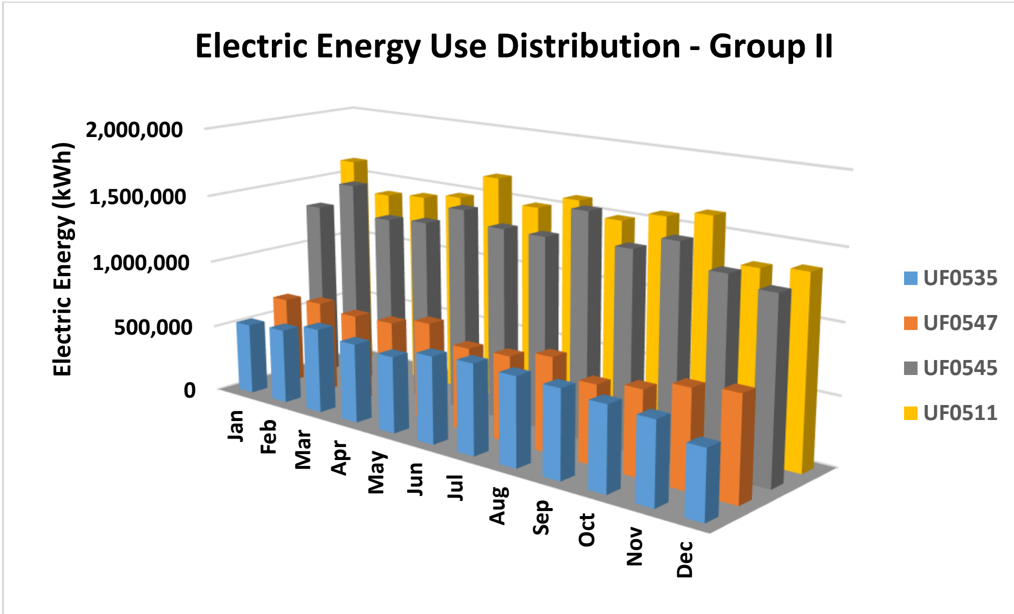


Figure 17. Electric energy use distribution for plants in Group II

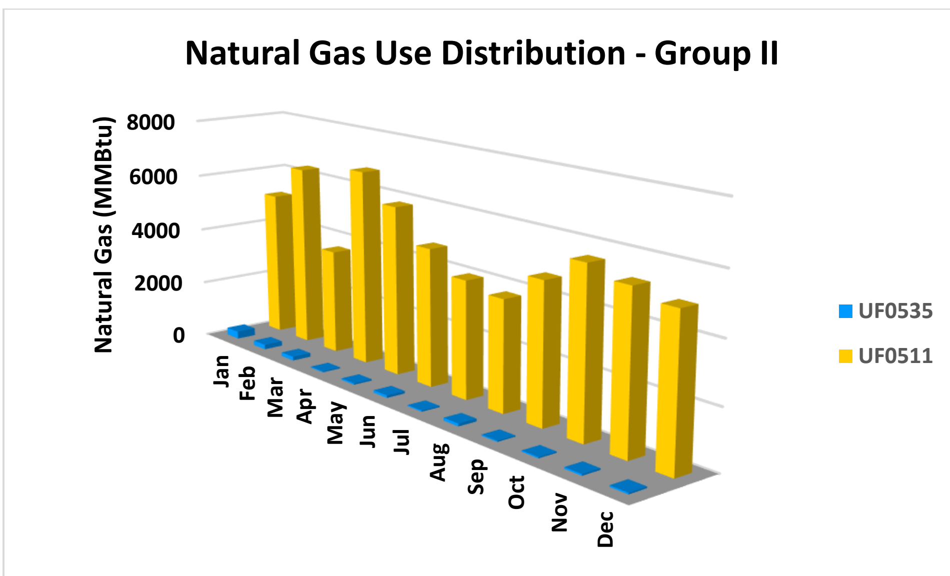


Figure 18. Natural gas energy use distributions for plants in Group II

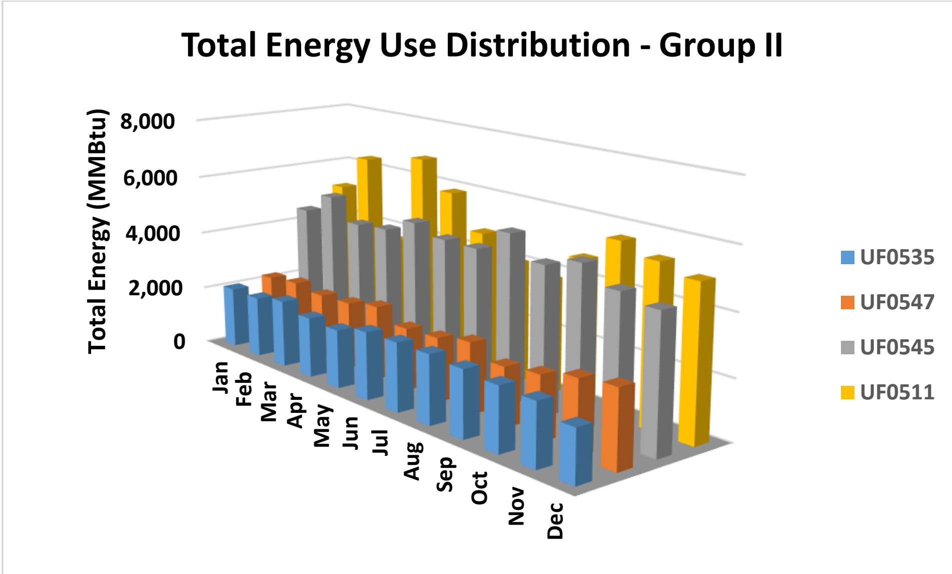


Figure 19. Total energy use distributions for plants in Group II

Bar Charts for Plants in Group III

Table 12. Electric Energy Use Distributions for Plants in Group III

	UF0542 Electricity (kWh)	UF0533 Electricity (kWh)	UF0544 Electricity (kWh)
Jan	605,784	776,000	991,200
Feb	560,684	670,800	1,030,800
Mar	572,934	594,400	986,400
Apr	583,893	851,787	1,090,800
May	548,319	848,633	1,005,600
Jun	599,858	962,315	1,089,600
Jul	576,003	871,200	1,060,800
Aug	523,182	848,400	1,098,000
Sep	569,600	965,600	1,028,400
Oct	616,556	791,600	1,010,400
Nov	534,668	812,800	1,012,800
Dec	557,195	897,600	915,600
Total Energy	6,848,676	9,891,135	12,320,400

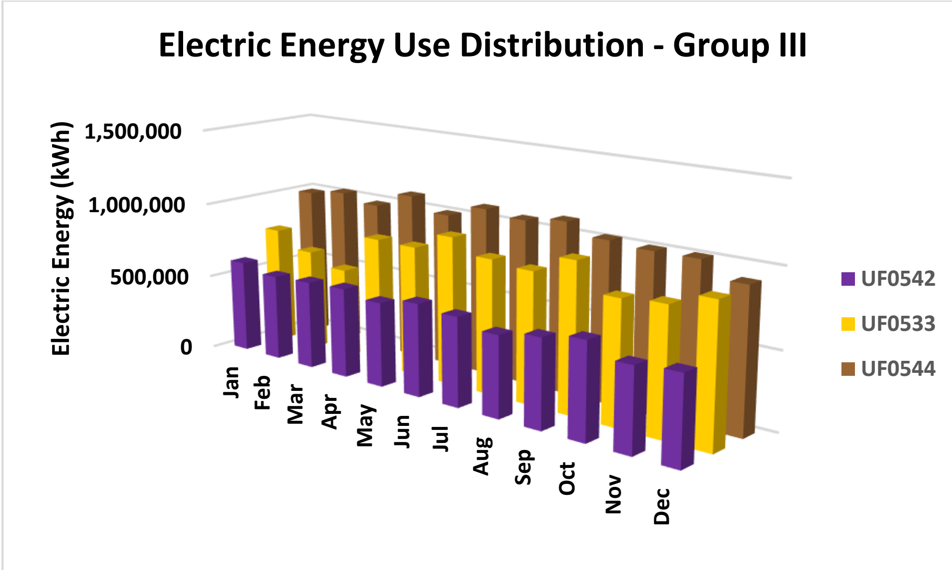


Figure 20. Electric energy use distributions for plants in Group III

Except for the plant of Report UF0533, all plants have a practically constant energy consumption throughout the year.

4.5 Energy Baseline Metrics

In this section we show the energy baseline for each plant, which is determined by examining the linear relationship between the total energy consumed in the facility (in MMBtus) and the amount of wastewater (in MG) treated with it. The baseline depends on many factors as is the plant operation and maintenance, type of equipment and their efficiencies, running hours, and electric loads, among other variables. The baseline represents the performance of the plant in terms of energy used to process wastewater during the period considered (one year). The relationship examined can be expressed according to the following:

$$E = m \times MG + b \qquad \text{with correlation} \quad R^2$$

Here "E" is the total energy used in the plant (electric and thermal), "m" is the slope and is a metric that represents the amount of energy use per MG of influent wastewater, and the quantity "b" represents the intercept. This is a quantity that reflects the amount of production-unrelated energy used in the plant. Finally, the correlation coefficient (R^2) is a measure (a percentage) of the consistency of the energy use in the treatment of wastewater in the plant during the period considered. The line itself represents the current energy baseline of the plant, and the data points above it are associated with more energy consumed, while those under it represent less energy consumed.

Table 13 summarizes the baseline parameters for all plants. The form of each plant baseline will be shown a little later.

Table 13. Energy Baselines for All Ten Plants

Group		**m** (MMBtu/MG)	**b** (MMBtu)	**R^2** (%)
I	UF0548	-1.4834	26,344	2.05
	UF0549	0.4032	12,283	0.51
	UF0540	4.1152	12,100	1.98
II	FU0511	5.8238	7,028.20	6.77
	UF0545	-0.2552	4,988.90	0.06
	UF0547	2.5126	1,386.90	13.98
	UF0535	1.2981	1,780.30	6.77
III	UF0544	-582.54	1.00E+06	5.47
	UF0542	0.6619	1,814.10	0.62
	UF0533	2,759.70	212,644	49.89

<u>The Correlation:</u>

In general, the better the correlation, the more consistent is the plant in using its energy to treat the influent water. In the plants surveyed, it has been observed that the smaller the capacity of the plant (e.g. plants in Group III) the better the correlation. For the ten plants surveyed, the average correlation was calculated to be as follows: 1.51 percent for Group I plants, 6.90 percent for Group II plants, and 18.66 percent for Group III plants.

<u>The Slope:</u>

The slope can have a positive or negative value. The negative value indicates that somehow the plant is implementing some projects that are conducive to less use of energy in the processing of wastewater. The slope is a metric that can be compared with slopes from previous years or from future years. It can also be compared with slopes obtained from other plants. Some of these metrics are based on algorithms that include the biochemical oxygen demand (BOD) distribution. In the energy audits that were performed on the ten plants under study this parameter was not included.

According to the US Department of Energy's Better Plants Program, the energy required to produce clean water through a wastewater treatment process is within the range of 8.02 to 11.26 MMBtu per MG. Accordingly, the plants audited were mostly found (with a couple of exceptions) to be below the range specified by DOE. Other values indicate that the needed energy to treat wastewater is about 1 kWh per m^3 or 12.92 MMBtu/MG. Again, the ten plants audited were largely found (with a couple of exceptions) to be below the specified range.

<u>The Intercept:</u>

As mentioned before, the intercept is a measure of the energy used in the plant but not for the treatment of wastewater, indicating that there is equipment running for more hours than necessary, or that other equipment is working at higher electric loads. This could also mean that there are equipment operating with lower efficiencies, or that there is older equipment in operation (e.g. standard motors instead of premium efficiency motors), or that there is equipment running for longer than necessary hours, etc. The higher the value of the "Intercept" the more unnecessary cost it represents.

The associated cost of reclaiming 1 MG of wastewater (slope) and the cost related to non-wastewater treatment energy are analyzed in the next section.

4.6 Energy Baseline Costs

Figure 21 below shows the total energy baseline representation for one of the ten plants surveyed. It is used here to provide a graphical display of the data given in Table 14 below.

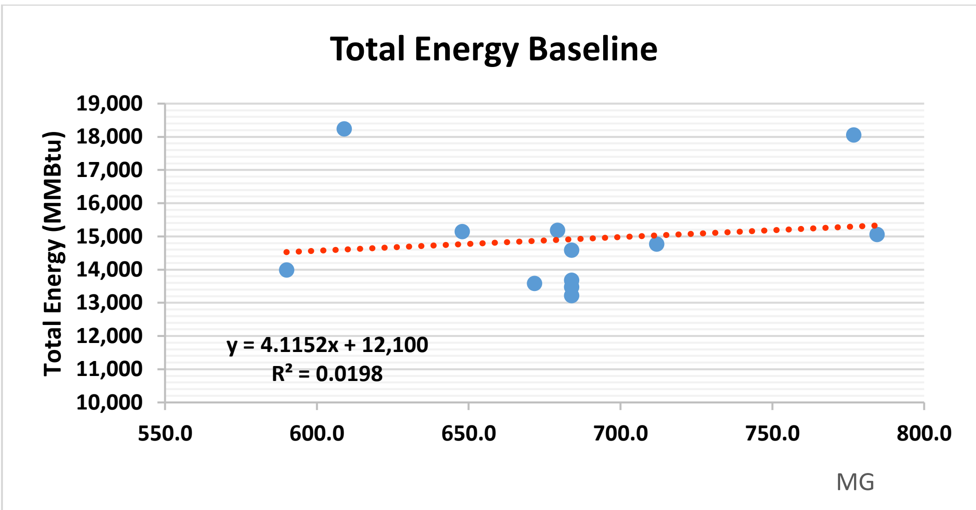


Figure 21. Total energy baseline for one of the plants surveyed

The linear relationship between energy usage and treated wastewater (MG) shows that the process energy does not have a good correlation coefficient (1.98 percent). The slope of the line (4.1152 MMBtu/MG) is the general metric of energy (biogas generated, electricity and natural gas, combined) used to treat 1 MG of wastewater.

From the total energy used by this plant (178,972.4 MMBtu/year), 54.28 percent of it correspond to natural gas usage, 39.28 percent to electricity and 6.44 percent to biogas (produced internally). As per the baseline equation, the corresponding amount of energy used by each source to process 1 MG of wastewater, is estimated as follows:

Electricity: 4.1152 MMBtu/MG x 0.5428 = 2.2337 MMBtu/MG

Natural Gas: 4.1152 MMBtu/MG x 0.3928 = 1.6165 MMBtu/MG

Biogas: 4.1152 MMBtu/MG x 0.0644 = 0.2650 MMBtu/MG

From here, the processing cost (PC) of 1 MG of wastewater will be:

Total Cost per MG = Cost from Electricity + Cost from Natural Gas
= (2.2337 MMBtu/MG x 293.1 kWh/MMBTU x $0.051/kWh) + (1.6165 MMBTU/MG x $5.511 /MMBTU)
= $33.39/MG + $8.91/MG
= $42.30/MG

The value of the slope of the baseline represents the energy usage per MG (4.1152 MMBtu) and thus the cost per MG will be $42.30.

On the other hand, the physical meaning of the intercept (12,100 MMBtu) is that it uncovers the energy that is used in the facility but not for processing purposes, before any wastewater is processed. Following the same procedure used above, the following parameters are obtained:

Electricity: 12,100 MMBtu/MG x 0.5428 = 6,567.88 MMBtu/MG

Natural Gas: 12,100 MMBtu/MG x 0.3928 = 4,752.88 MMBtu/MG

Biogas: 12,100 MMBtu/MG x 0.0644 = 779.24 MMBtu/MG

From here the associated non-processing energy cost (NPC) is estimated as follows:

NPC = Cost from Electricity + Cost from Natural Gas
= (6,567.88 MMBtu/MG x 293.1 kWh/MMBTU x $0.051/kWh) + + (4,752.88 MMBTU/MG x $5.511/MMBTU)
= $98,177 + $26,193 = $124,370

This non-processing energy cost ($124,370) represents about 6.10 percent of all the energy costs between electricity and natural gas used in this plant. This value gives an indication that there are possibilities to save energy in the plant, and that there is equipment that most probably remains idle during and after the different processes. Any reduction of these metrics multiplied by the amount of wastewater processed will represent not only better metrics but also resources saved.

The results of the energy costs and the non-treatment costs for all ten plants are summarized in Table 14.

Table 14. Associated Baseline Costs

Group		Energy Cost (from the slope m) ($/MG)	Non-Treatment Cost (from the intercept b) ($)
I	UF0548	13.71	243,566
	UF0549	6.65	202,394
	UF0540	42.3	124,370
II	FU0511	102.98	124,294
	UF0545	4.67	91,390
	UF0547	46.55	25,679
	UF0535	22.25	38,517
III	UF0544	54.8	94,000
	UF0542	15.52	42,453
	UF0533	173.9	13,397

4.7 Different Energy Use for Same Amount of Wastewater Treated

From the baseline example shown in Figure 21, additional insight can be obtained. To process about 600 MG of water, the plant is using two different amounts of energy (13,992 MMBtu and 18,239 MMBtu) as seen from the first two points on the left of the figure. This means that about 4,247 MMBtu extra energy is used to treat practically the same amount of wastewater. This represents about $43,650/yr of extra expense to treat the same amount of wastewater. These two different points show that the plant has in fact processed wastewater at a lower cost. The same situation, but with lower energy and cost values, is observed in the last two points (on the right) of Figure 21. Although these points can be outliers, their removal will improve the goodness of the regression. This simply indicates that there are opportunities that can provide significant savings in the plant.

4.8 Same Energy Use for Different Amounts of Wastewater Treated

Similarly, and by considering the first point to the left in Figure 21 and the last point to the right in the same figure, we observe that they represent the same amount of energy (14,522 MMBtu) that is used to process two different amounts of wastewater (i.e. 590 MG and 784 MG). This indicates that the plant has been able to process about 33 percent more wastewater (194 MGs) using practically the same amount of energy. Again, this means that there is significant room for improvement.

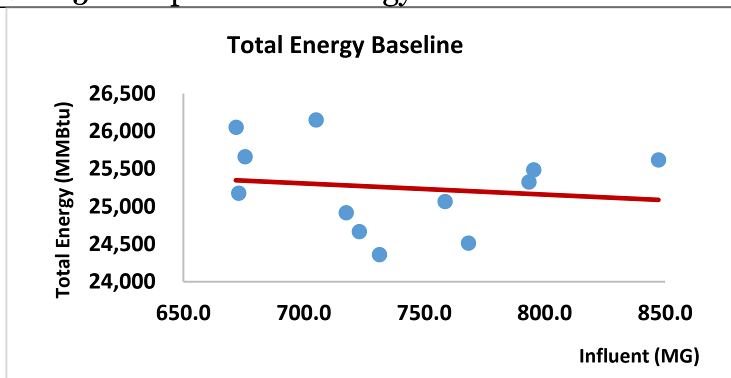
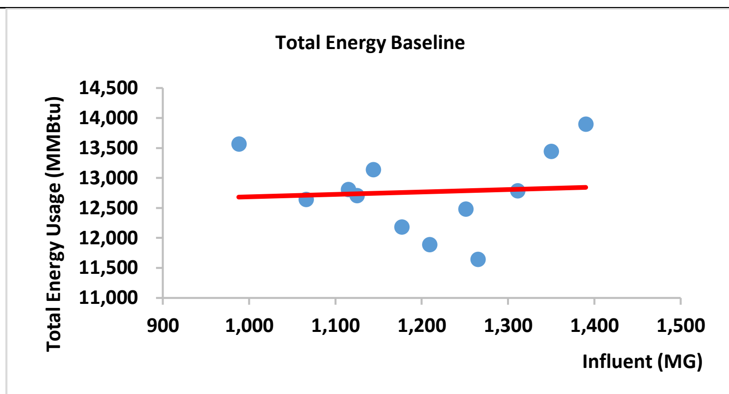
4.9 Summary of Metrics for Individual Plants

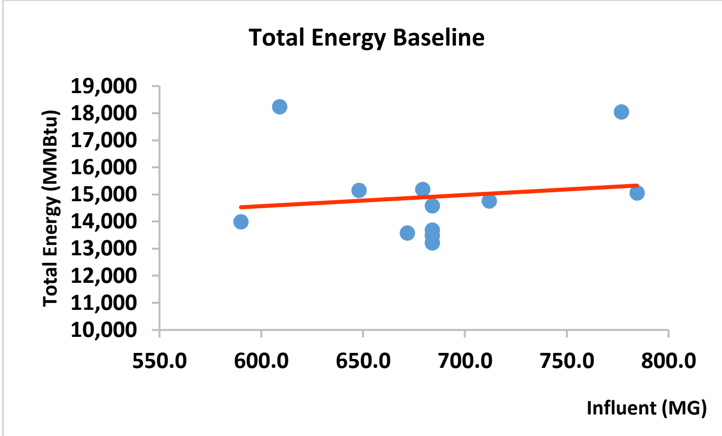
In this section, the total energy baseline analysis for all ten plants is shown in Tables 15, 16, and 17 organized by the respective groups of the individual plants. The tables contain the baseline graphs, the regression analysis parameters, and the associated costs the plants incur to process 1 MG of influent as discussed before.

4.9.1 Energy and costs baseline metrics for plants in Group I

A comparison of energy baseline and costs among plants in Group I is provided in Table 15.

Table 15. Comparison of Energy Baselines and Costs for Group I Plants

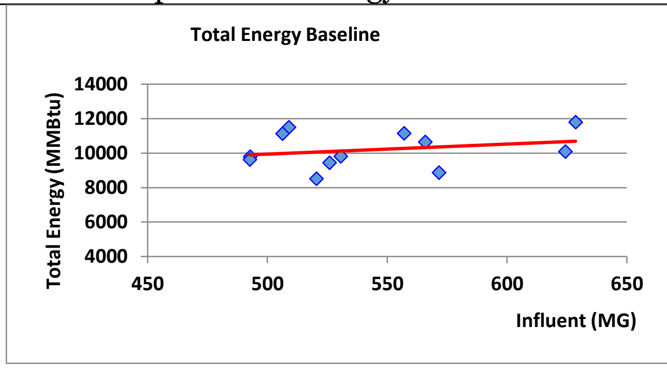
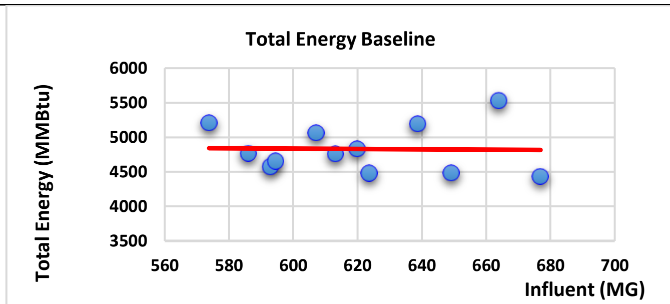
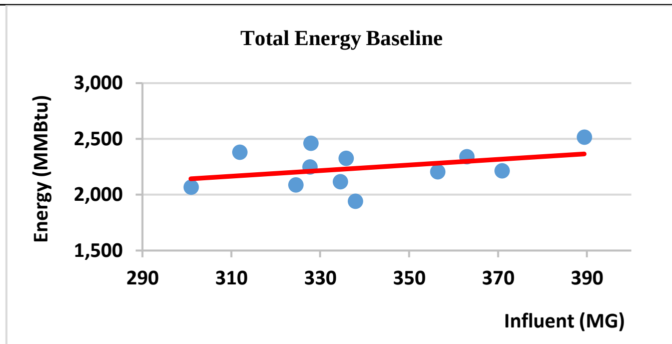
UF0548		E = -1.4834 x MG + 26,344 R^2 = 0.0205 **Costs per MG:** Electric: $11.09/MG Thermal: $2.62/MG **Total: $13.71/MG** **Non-Process Energy Costs:** Electric: $197,012 Thermal: $46,554 **Total: $243,566**
UF0549		E = 0.4032 x MG + 12,283 R^2 = 0.0051 **Costs per MG:** Electric: $6.54/MG Thermal: $0.068/MG Diesel: $0.041/MG **Total: $6.65/MG** **Non-Process Energy Costs:** Electric: $199,095 Thermal: $2,047 Diesel: $1.253 **Total: $202,394**

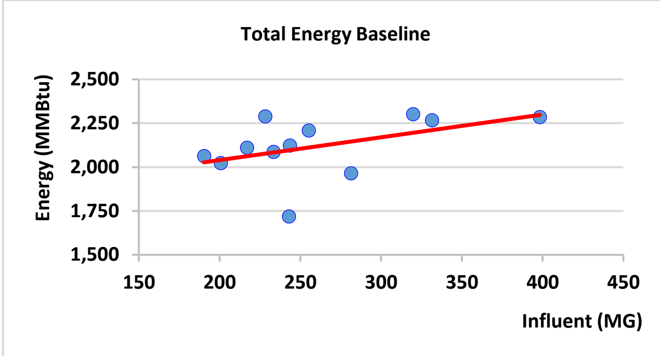
UF540		E = 4.1152xMG + 12,100 R^2 = 0.0198 **Costs per MG:** Electric: $33.39/MG Thermal: $8.91/MG **Total: $42.30/MG** **Non-Process Energy Costs:** Electric: $98,177 Thermal: $26,193 **Total: $124,370**

4.9.2 Energy and costs baseline metrics for plants in Group II

A comparison of energy baseline and costs among plants in Group II is provided in Table 16.

Table 16. Comparison of Energy Baseline and Costs for Plants in Group II

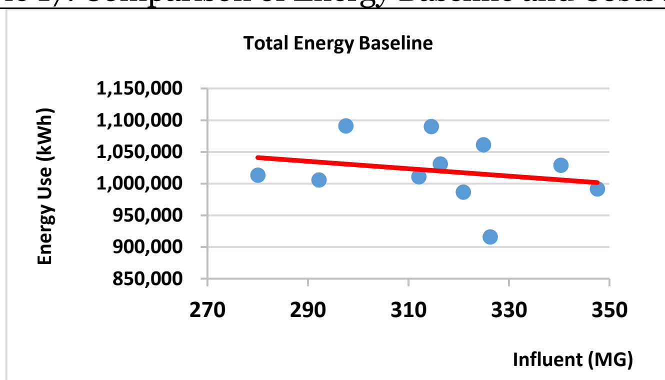
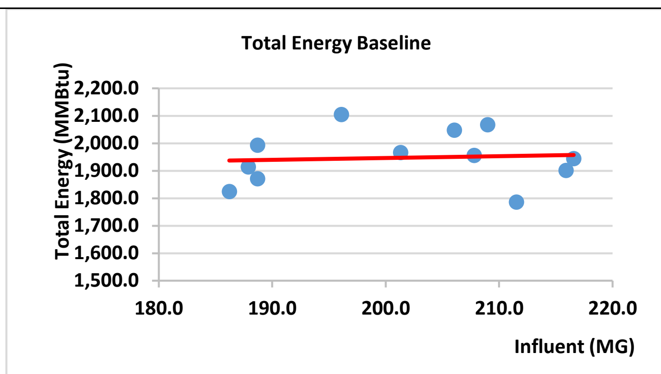
UF0511		E = 5.8238 x MG + 7,028.2 R^2 = 0.0677 **Costs per MG:** Electric: $86.495/MG Thermal: $16.485/MG **Total: $102.980/MG** **Non-Process Energy Costs:** Electric: $104,399 Thermal: $19,895 **Total: $124,294**
UF054 5		E = -0.2552 x MG + 4,988.9 R^2 = 0.0006 **Costs per MG:** Electric: $4.67/MG **Total: $4.67/MG** **Non-Process Energy Costs:** Electric: $91,390 **Total: $91,390**
UF054 7		E = 2.5126 x MG+ 1,386.9 R2 = 0.1398 Costs per MG: Electric: $46.55/MG Total: $46.55/MG Non-Process Energy Costs: Electric: $25,679 Total: $25,679

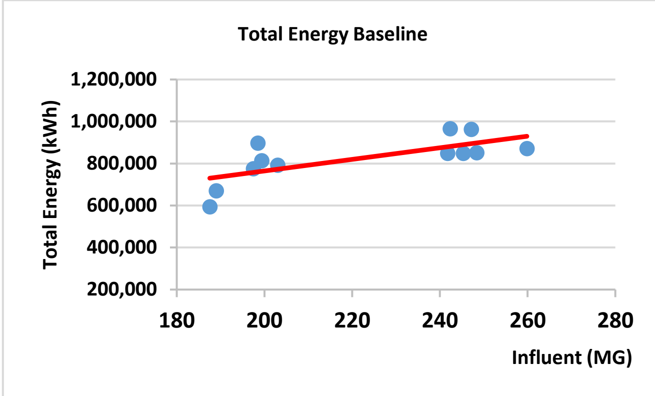
UF053 5		E = 1.2981 x MG + 1,780.3 R2 = 0.0677 Costs per MG: Electric: $20.07/MG Thermal: $2.18/MG Total: $22.25/MG Non-Process Energy Costs: Electric: $27,529 Thermal: $2,980 Total: $38,517

4.9.3 Baseline and Metrics Group III

A comparison of energy baseline and costs among plants in Group III is provided in Table 17.

Table 17. Comparison of Energy Baseline and Costs for Plants in Group III

UF0544		E = -582.54 x MG + 1.0E+6 R^2 = 0.0547 **Costs per MG:** Electric: $54.80/MG Thermal: $0.0/MG **Total: $54.80/MG** **Non-Process Energy Costs:** Electric: $94,000 Thermal: $0.0 **Total: $94,000**
UF0542		E = 0.6619 x MG + 1,814.1 R^2 = 0.0062 **Costs per MG:** Electric: $15.52/MG Thermal: $0.0/MG **Total: $15.52/MG** **Non-Process Energy Costs:** Electric: $42,453 Thermal: $0.0 **Total: $42,453**

UF0533		E = 2,759.7 x MG + 212,644 R^2 = 0.4989 **Costs per MG:** Electric: $173.9/MG Thermal: $0.0/MG **Total: $173.9/MG** **Non-Process Energy Costs:** Electric: $13,397 Thermal: $0.0 **Total: $13,397**

CHAPTER 5

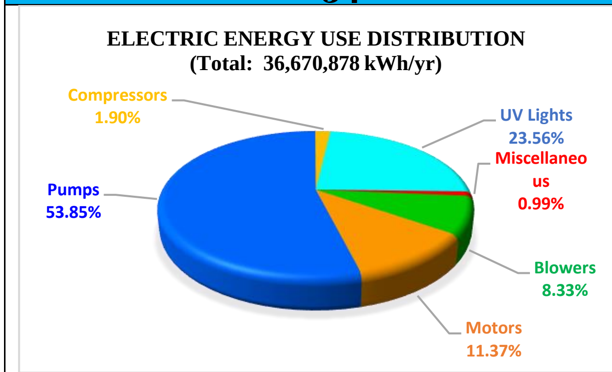
5. ENERGY BALANCE

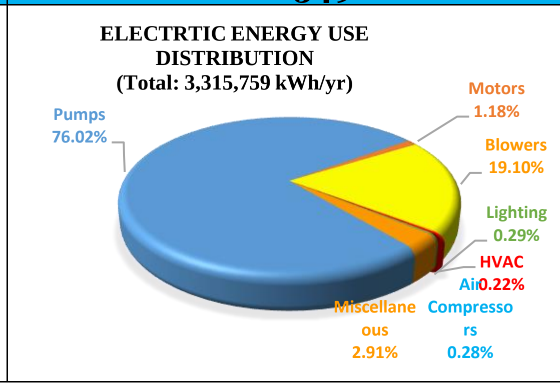
This chapter shows the electric energy balance (EB) for all ten plants surveyed. The EB is an inventory of the major electric energy consuming equipment in the facility. In it, the approximate energy consumed by each electric piece of equipment and its cost are calculated. The estimate is based on information provided by personnel at the plant, by measurements performed during the audits (electric current, electric voltage, infrared thermography, light intensity, relative humidity, and compressed air and steam leaks, etc.), and by team observations and discussions with plant personnel. The EB is developed to ensure that the electric energy used by the equipment is neither over- nor under-estimated. The energy balance is made by comparing the estimates of the total energy (kWh/yr) used by the equipment and their associated costs ($/yr) with the actual annual electric energy bills. The deviation is to be kept to below 2 percent at all times. Only the energy use distribution is shown as the cost distribution has the same form.

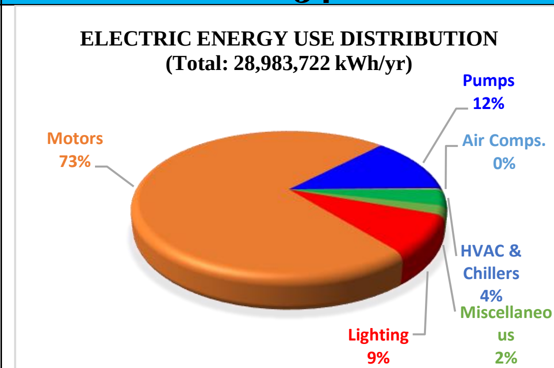
5.1 Electric Energy Balance – Group I

Table 18. Electric Energy Balance for WWTPs in Group I

UF0548	UF0549	UF0540



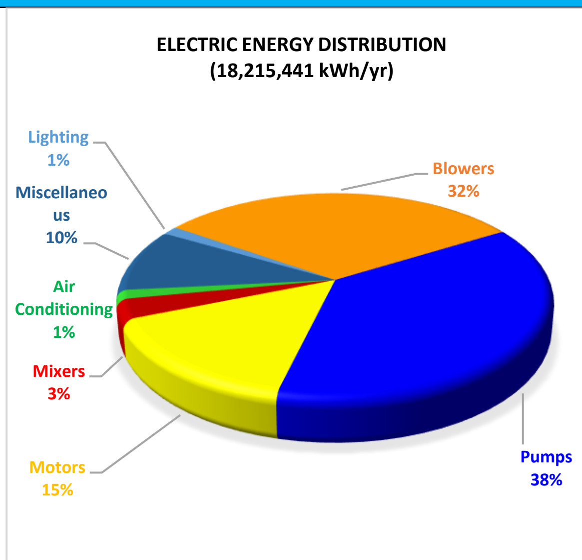




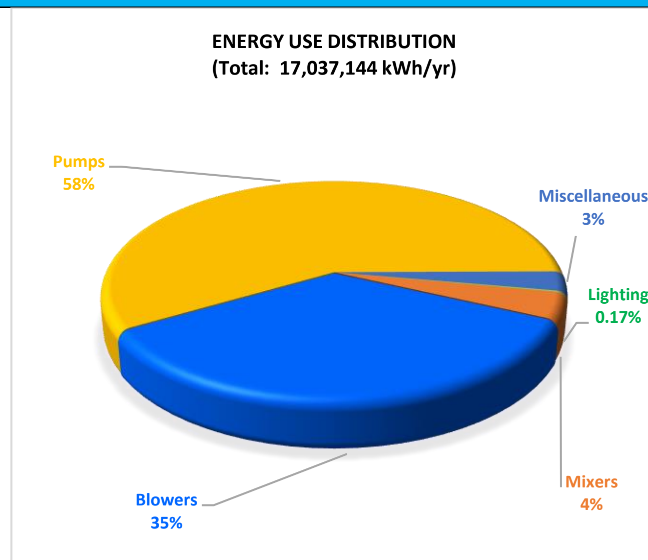
5.2 Electric Energy Balance – Group II

Table 19. Electric Energy Balance for WWTPs in Group II

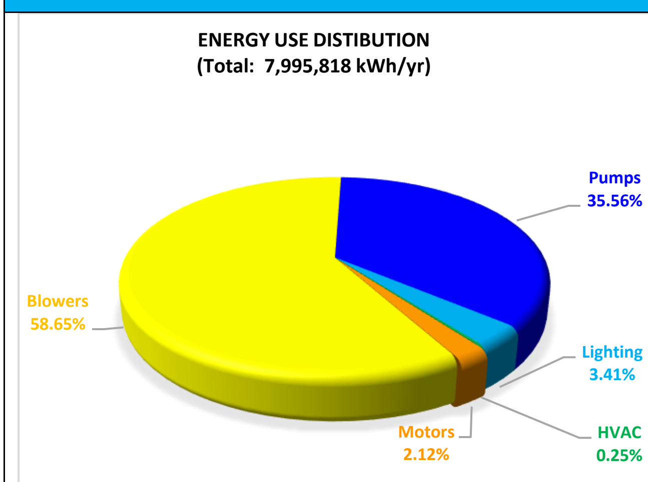
UF0511



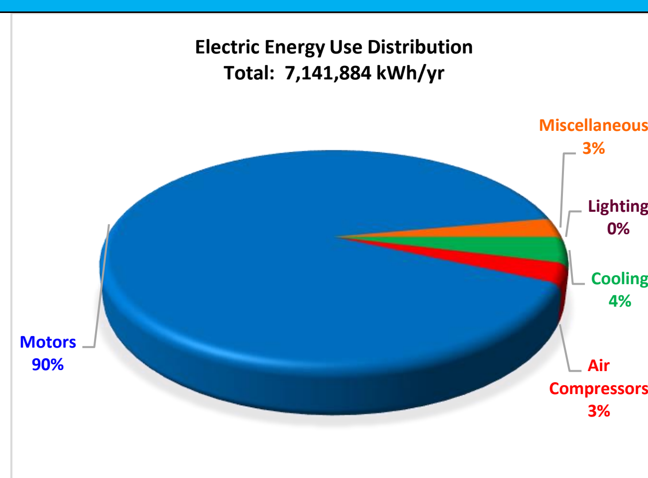
UF0545



UF0547

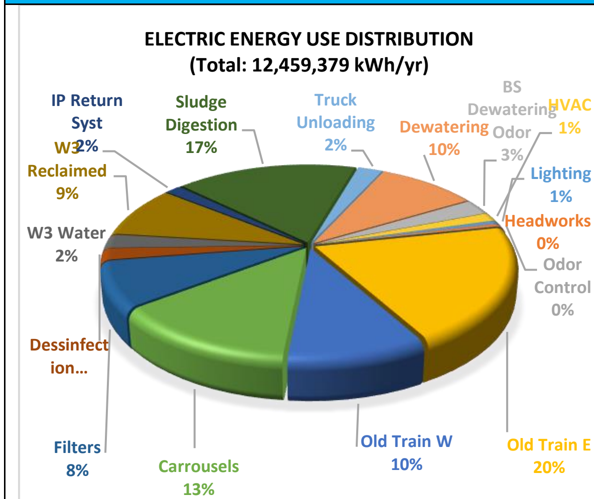


UF0535



5.3 Electric Energy Balance – Group III

Table 20. Electric Energy Balance for WWTPs in Group III

<table>
<tr><th>UF0544</th><th>UF0542</th><th>UF0533</th></tr>
<tr>
<td>
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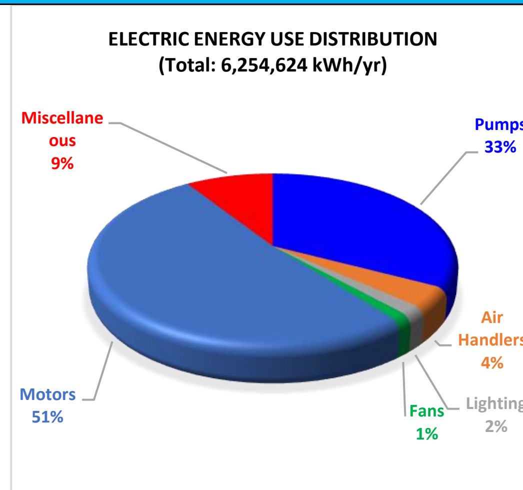
<td>
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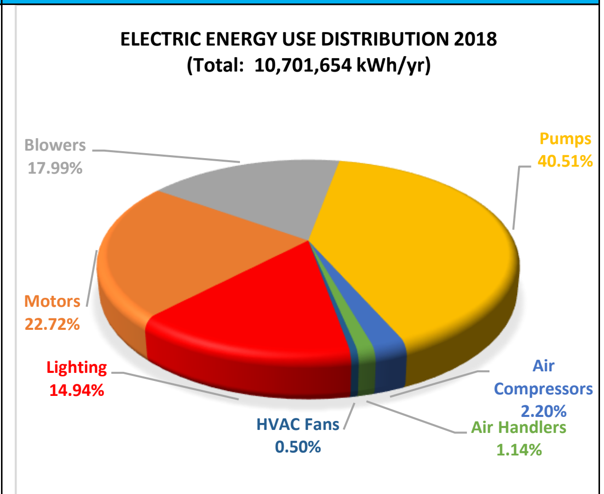
<td>
</td>
</tr>
</table>

5.4 Electric Equipment Users

The major electric energy equipment users in WWTPs are pumps, motors, and blowers. Although the percentage of energy they use varies, among all the plants surveyed, they consume between 74 and 96 percent of the total energy used. Therefore, these systems have a virtual monopoly on most of the potential energy savings opportunities.

It is important to note that while WWTPs typically run all year long (8,760 hours per year), this does not necessarily mean that all the electric equipment in the plants are running the same number of hours or at the same time. They also do not run at the same electric load. Electric equipment also has different efficiencies, power factors, age, and operating conditions, just to name a few.

CHAPTER 6

6. BEST PRACTICES

In addition to identifying energy savings opportunities at each facility where an audit was performed, this project also looked at identifying best practices that could be easily adopted by other WWTPs in their pursuit of energy and financial savings in water and wastewater treatment. The energy efficiency strategies described provide information on energy savings opportunities, which can be used as a basis for discussing energy management goals with water and wastewater treatment facility managers. In general, the lower the number of assessment recommendations (ARs) that the audit teams can find, the more likely that a larger number of best practices exist in the plants. These identified best practices are listed in Tables 21, 22 and 23.

6.1 Energy Best Practices

Table 21. Energy Best Practices in Place in WWTPs

ARs	GROUP I			GROUP II				GROUP III		
	UF0548	UF0549	UF0540	UF0511	UF0545	UF0547	UF0535	UF0544	UF0542	UF0533
Use of a supervisory control and data acquisition (SCADA) system	√				√		√		√	
Use of variable frequency drives	√	√	√	√	√	√	√	√		√
Some equipment uses soft starters	√					√		√		
Some buildings have skylights	√		√		√		√	√		
Have some automatic control systems	√									
Have high efficiency lighting installed	√	√	√		√	√		√	√	√
Have high efficiency motors and pumps	√									
Have solenoid values in some air compressors		√								
Have heat exchangers for the sludge		√								
Have photocells to control outside lights		√					√			
Have skylights		√						√		
Have some occupancy sensors		√	√	√						
Use of uninterruptible power supply (UPS) systems		√				√			√	
Have power generators		√			√	√		√	√	
Biogas production from the sludge			√							
Have exhaust fans			√							
Have energy and carbon foot printing goals			√							
Have mass flow meters and gas meters installed			√							
Submetering energy use			√	√		√				
HVAC is well insulated				√						
Have a PLC system					√	√				
Have oxygen sensor in boilers					√					

ARs	UF0548	UF0549	UF0540	UF0511	UF0545	UF0547	UF0535	UF0544	UF0542	UF0533
Cascade water for natural aeration					√					
Pick-up trucks work on biofuels					√					
Use of sensors to control chemicals						√				
UV channels controlled for water flow						√				
Control rooms are air conditioned							√		√	√
Aeration in biodigesters								√		
Check for pannels overheating								√		
Shut down equipment to control demand								√		
Use cogged-V belts for some motors									√	
Have some redundant equipment for possible failures										√
Fresh air supplied to compressors room										√

6.2 Productivity Enhancement Best Practices

Table 22. Productivity Enhancement Best Practices in Place in WWTPs

ARs	GROUP I			GROUP II				GROUP III		
	UF0548	UF0549	UF0540	UF0511	UF0545	UF0547	UF0535	UF0544	UF0542	UF0533
Have well qualified management personnel (Six sigma black belt)	√			√				√	√	
The plant reuses some of the treated water in the process	√					√				
In-house produced biogas used by dryers	√									
Bobcat is used to clean canals from sand	√									
You have an expansion plan for the plant to satisfy increasing demand		√								
Have heat exchangers for sludge treatment		√								
Have biodigesters to treat the sludge		√								
Have capital investments plans					√					
Have flowmeters					√			√		

Use color coding for pipes			√		
Prepared to absorb overflow				√	
Have chlorine monitor for instant check				√	
Use a polymer to handle sludge			√		
Do a continuous flush-out to clean algae				√	
Use UV lamps to disinfect water					√
Use advanced bacteria to improve productivity					√

6.3 Waste Management Best Practices

Table 23. Waste Management Best Practices in Place in WWTPs

ARs	GROUP I			GROUP II				GROUP III		
	UF0548	UF0549	UF0540	UF0511	UF0545	UF0547	UF0535	UF0544	UF0542	UF0533
Use some of the reclaim water for irrigation		√	√		√			√	√	
A fertilizer is produced from the sludge			√					√	√	
You recycle most of your waste					√	√				
You have good odour control practices					√	√		√	√	
Least disposal of nitrogen into water bodies					√					

CHAPTER 7

7. EVALUATED ENERGY SAVINGS OPPORTUNITIES

This chapter contains a summary of the evaluated energy, productivity enhancement and waste reduction savings opportunities, shown as assessment recommendations (ARs).

7.1 Summary of Energy Savings Opportunities

Table 24. Summary of Energy Assessment Recommendations (ARs).

ARs	GROUP I			GROUP II				GROUP III		
	UF0548	UF0549	UF0540	UF0511	UF0545	UF0547	UF0535	UF0544	UF0542	UF0533
Replace blowers with air compressors	√	√				√				
Turn on the UV controller	√									
Install high-efficiency motors	√	√			√	√	√	√	√	√
Put oxygen sensor in boiler's exhaust	√									
Install a CHP system		√								
Install CHP or CNG syst. using biogas				√						
Install high-efficiency lighting		√	√	√			√			
Insulate tanks			√							
Enhance biogas generation			√							
Install occupancy sensors			√				√			
Replace V-belts with cogged V-belts			√		√	√	√			
Install an energy management System			√	√						√
Preheat the air to the dryer				√						
Install O_2 sensor in boiler exhaust				√			√			
Install variable frequency drives					√				√	√
Install heat recovery for the boiler							√			
Install a photovoltaic system								√		
Install higher eff. blades in aerators								√		
Turn off the digester's pumps								√		
Install pipes for biomass transport								√		
Install timers for outside lights								√		
Treat rejected water with ozone									√	
Optimize comp. air vol. generation										√

ARs	UF0548	UF0549	UF0540	UF0511	UF0545	UF0547	UF0535	UF0544	UF0542	UF0533
Install a back-up generator switch										√
Energy Cost Savings ($/yr)	**480,698**	**274,070**	**331,342**	**222,530**	**128,672**	**256,917**	**50,986**	**146,122**	**95,000**	**120,627**
% of Energy Costs Saved	**17.16**	**8.16**	**16.22**	**11.82**	**12.10**	**51.73**	**10.00**	**10.75**	**17.34**	**19.43**

7.2 Summary of Productivity Enhancement Opportunities

Table 25. Summary of Productivity Assessment Recommendations (ARs)

ARs	GROUP I			GROUP II				GROUP III		
	UF0548	UF0549	UF0540	UF0511	UF0545	UF0547	UF0535	UF0544	UF0542	UF0533
Install a reactor for nutrient recovery	√	√		√						
Automate the aeration process								√		
Productivity Cost Savings ($/yr)	**493,101**	**492,292**		**495,807**				**70,421**		

7.3 Summary of Waste Management Savings Opportunities

Table 26. Summary of Waste Management Assessment Recommendations (ARs)

ARs	GROUP I			GROUP II				GROUP III		
	UF0548	UF0549	UF0540	UF0511	UF0545	UF0547	UF0535	UF0544	UF0542	UF0533
Install a biodigester										√
Cost Savings ($/yr)										**396,790**

7.4 Total Savings Opportunities

In this section the total savings, including energy, productivity enhancement and waste management, are displayed for all ten WWTPs audited.

Table 27. Summary of Total Cost Savings for Energy, Productivity, and Waste Management ARs

ARs	GROUP I			GROUP II				GROUP III		
	UF0548	UF0549	UF0540	UF0511	UF0545	UF0547	UF0535	UF0544	UF0542	UF0533
TOTAL COST SAVINGS	973,799	766,362	331,342	718,337	128,672	256,917	50,986	216,543	95,000	517,417

7.5 Summary of Savings Opportunities per Plant

The evaluated energy, productivity enhancement and waste reduction savings assessment recommendations (ARs) for each of the ten audited WWTPs are shown in this section.

7.5.1 Summary of savings opportunities for plants in Group I

Table 28. Evaluated Assessment Recommendations for UF0548

ASSESSMENT RECOMMENDATIONS (ARs)

Summary of Savings and Costs

AR Number and Description		Potential Savings ($/yr)	Implementation Cost ($)	Simple Payback Period (yr)	Return on Investment (% /yr)	Energy Savings (kWh/yr)	Demand Savings (kW/mo)	CO_2 Reduction (tons CO_2/yr)
ENERGY ASSESSMENT RECOMMENDATIONS								
1	Turn on the UV controller	27,216	None	Immediate	-	432,000	-	229.91
2	Install high efficiency motors	23,699	74,548	3.15	31.79	376,179	125.39	200.2
3	Install an oxygen sensor in the boiler's exhaust	16,062	2,800	0.17	573.64	*5,408 MMBtu/yr*	-	-
	Energy Sub-Total	66,977	77,348	1.15	86.59	808,179 *5,408 MMBtu/yr*	125.39	430.11
PRODUCTIVITY ASSESSMENT RECOMMENDATIONS								
4	Install a reactor for nutrient recovery	493,101	1,875,550	3.8	26.29	(109,500)	(12.5)	(58.28)

Grand Total	**560,078**	**1,952,898**	**3.49**	**28.68**	**698,679 Wh/yr** ***5,408 MMBtu/yr***	**112.89**	**371.83**

Table 29. Evaluated Assessment Recommendations for UF0549

ASSESSMENT RECOMMENDATIONS (ARs)
Summary of Savings and Costs

AR Number and Description		Potential Savings ($/yr)	Implementation Cost ($)	Simple Payback Period (yr)	Return on Investment (% /yr)	Energy Savings (kWh/yr)	Demand Savings (kW/mo)	CO_2 Reduction (tons CO_2/yr)
ENERGY ASSESSMENT RECOMMENDATIONS								
1	Install a combined heat and power system	737,260	2,600,000	3.53	28.36%	17,000,000 *99,436 MMBtu/yr*	2,000	-
2	Install high efficiency motors	73,018	68,138	0.93	107.16%	930,251	181.71	495.08
3	Install high efficiency lighting	6,001	2,904	0.48	206.65	76,000	15.2	40.45
	Sub-total Energy ARs	816,279	2,671,042	3.27	30.56	18,006,251 *99,436 MMBtu/yr*	2,196.85	535.53
PRODUCTIVITY ASSESSMENT RECOMMENDATIONS								
4	Install a reactor for nutrients recovery	492,292	1,875,550	3.81	26.25%	(109,500)	(12.5)	(58.28)
Total		**1,308,571**	**4,546,592**	**3.47**	**28.78%**	**17,896,751** ***99,436 MMBtu/yr***	**2,184.35**	**477.25**

Table 30. Evaluated Assessment Recommendations for UF0540

ASSESSMENT RECOMMENDATIONS (ARs)
SUMMARY OF SAVINGS AND COSTS

AR Number and Description		Potential Savings ($/year)	Implementation Cost ($)	Simple Payback Period (year)	Return on Investment (%/year)	Energy Savings (kWh/year) *(MMBtu/yr)*	Demand Savings (kW)	Reduction on CO_2 Emissions (tons CO_{2-e})
ENERGY ASSESSMENT RECOMMENDATIONS								
1	Insulate tanks	$128,693	$34,812	0.27	369.68	***23,352***	-	-
2	Enhance biogas generation	$99,716	$392,375	3.93	25.41	***18,093.96***	-	-
3	Install high efficiency lighting	$35,477	$20,256	0.57	175.14	545,730	108	290.44
4	Install occupancy sensors	$32,246	$1,280	0.04	2,519.26	632,284	-	336.5
5	Replace V-belts with cogged V-belts	$16,996	0	Immediate	N/A	324,075	-	172.47
6	Install an energy management system	$18,214	$25,600	1.41	71.15	357,139	-	190.07
Grand Total		**$331,342**	**$474,323**	**1.43**	**69.86**	**1,859,228** ***41,445.96***	**108**	**989.48**

7.5.2 Summary of Savings Opportunities for Plants in Group II

Table 31. Evaluated Assessment Recommendations for UF0511

ASSESSMENT RECOMMENDATIONS (ARs) SUMMARY OF SAVINGS AND COSTS

AR Number and Description		Potential Savings ($/yr)	Implementation Cost ($)	Simple Payback Period (yr)	Return on Investment (%/yr)	Energy Savings (kWh/yr)	Demand Savings (kW)
ENERGY ASSESSMENT RECOMMENDATIONS							
1	Install a CHP or a CNG system using biogas	5,783,172	13,354,800	2.31	43.3	471.46 MMscf/yr 60,666 MMBtu/yr	-
2	Preheat the air to the dryer	200,909	20,000	0.10	1,005	21,292 MMBtu/yr	-
3	Install high efficiency lighting System	9,022	1,400	1.55	64.4	143,080	39.2
4	Install energy monitoring system	7,447	20,214	2.71	28.5	361,488	-
5	Install O_2 sensor in boiler exhaust	5,152	2,800	0.54	184.0	546 MMBtu/yr	N/A
	Energy Sub-Total	6,005,702	13,581,114	2.26	44.2	471.46 MMscf/yr 82,504 MMBtu/yr 504,568 kWh/yr	39.2
PRODUCTIVITY ASSESSMENT RECOMMENDATIONS							
6	Install a reactor for nutrient recovery	495,807	1,875,550	3.78	26.4	(109,500)	(12.5)
Grand Total		**$6,501,509 /yr**	**$15,456,664**	**2.38yrs**	**42.1%/yr**	**471.46 MMscf/yr 82,504 MMBtu/yr 395,068 kWh/yr**	**26.7 kW**

Table 32. Evaluated Assessment Recommendations for UF0545

ASSESSMENT RECOMMENDATIONS (ARs)
SUMMARY OF SAVINGS AND COSTS

AR Number and Description		Potential Savings ($/year)	Implementation Cost ($)	Simple Payback Period (year)	Return on Investment (%/year)	Energy Savings (kWh/year)	Demand Savings (kW/mo)	Carbon Di-Oxide Reduction (tons CO_2/yr)
ENERGY ASSESSMENT RECOMMENDATIONS								
1	Install high efficiency motors	67,090	20,230	0.30	331.64	1,073,441	161.26	521.29
2	Install variable frequency drives	51,046	88,272	1.73	57.83	816,732	-	434.66
3	Replace V-belts with cogged V-belts	10,536	0	Immediate	N/A	158,869	-	84.55
Grand Total		**128,672**	**108,502**	**0.84**	**118.59**	**1,049,042**	**161.26**	**1,040.50**

Table 33. Evaluated Assessment Recommendations for UF0547

ASSESSMENT RECOMMENDATIONS (ARs)
SUMMARY OF SAVINGS AND COSTS

AR Number and Description		Potential Savings ($/year)	Implementation Cost ($)	Simple Payback Period (year)	Return on Investment (%/year)	Energy Savings (kWh/year)	Demand Savings (kW/mo)	Carbon Di-Oxide Reduction (tons CO_2/yr)
ENERGY ASSESSMENT RECOMMENDATIONS								
1	Replace blowers with air compressors	234,675	218,100	0.93	107.60	3,725,000	745	1,982.45
2	Install high efficiency motors	18,816	17,893	0.95	105.16	298,668	47.91	158.95
3	Replace V-belts with cogged V-belts	3,426	0	Immediate	N/A	47,115	-	25.07
Grand Total		**256,917**	**235,993**	**0.92**	**108.87**	**4,70,783**	**792.91**	**1,040.50**

Table 34. Evaluated Assessment Recommendations for UF0535

ASSESSMENT RECOMMENDATIONS (ARs)
SUMMARY OF SAVINGS AND COSTS

AR Number and Description		Potential Savings ($/year)	Implementation Cost ($)	Simple Payback Period (year)	Return on Investment (%/year)	Energy Savings (kWh/year)	Demand Savings (kW/mo)	Reduction on CO_2 Emissions (tons CO_{2-e}/yr)
ENERGY ASSESSMENT RECOMMENDATIONS								
1	Install high efficiency motors	35,226	127,650	3.62	27.60	460,169	175.23	244.9
2	Replace V-belts with cogged-V belts	5,527	0	Immediate	N/A	87,971	-	46.82
3	Install occupancy sensors	3,486	3,283	0.94	106.18	63,377	-	33.7
4	Install high efficiency lighting	3,073	2,563	0.83	119.86	47,771	7.87	25.4
5	Install heat recovery for the boiler	2,330	6,000	2.58	38.83	*56.76 MMBtu/yr*	N/A	-
6	Install an oxygen sensor in the boiler exhaust	1,344	1,400	1.04	96.00	*32.73 MMBtu/yr*	N/A	-
Grand Total		**$50,986**	**$140,896**	**2.76**	**36.19%**	**659,288** ***89.5 MMBtu/yr***	**183.1**	**350.82**

7.5.3 Summary of Savings Opportunities for Plants in Group III

Table 35. Evaluated Assessment Recommendations for UF0544

ASSESSMENT RECOMMENDATIONS (ARs)

SUMMARY OF SAVINGS AND COSTS

AR Number and Description		Potential Savings ($/year)	Implementation Cost ($)	Simple Payback Period (year)	Return on Investment (%/year)	Energy Savings (kWh/year) *(MMBtu/yr)*	Demand Savings (kW)	Reduction on CO_2 Emissions (tons CO_{2-e}/yr)
ENERGY ASSESSMENT RECOMMENDATIONS								
1	Install a photovoltaic system	53,586	$333,760	6.23	16.06	570,064	-	303.4
2	Install high efficiency motors	46,696	42,592	0.91	109.64	392,625	83.67	208.96
3	Install higher efficiency blades in aerators	30,318	90,000	2.97	33.69	322,535	-	171.65
4	Turn off the digesters' pumps	12,417	913	0.07	1,360	132,100		70.30
5	Install pipes for biomass transportation	2,082	2,730	1.31	76.26	-	-	-
6	Install timers for outside lights	1,023	$812	0.79	125.99	10,886	-	5.79
	Sub Total Energy	146,122	470,807	3.22	31.04	1,428,210	83.67	760.10
PRODUCTIVITY ASSESSMENT RECOMMENDATIONS								
7	Automate the aeration process	70,421	37,386	0.53	188.36	749,160	-	398.70
	Grand Total	**216,543**	**508,193**	**2.35**	**42.61**	**2,177,370**	**83.67**	**1,158.80**

Table 36. Evaluated Assessment Recommendations for UF0542

ASSESSMENT RECOMMENDATIONS (ARs)
SUMMARY OF SAVINGS AND COSTS

AR Number and Description		Potential Savings ($/year)	Implementation Cost ($)	Simple Payback Period (year)	Return on Investment (%/year)	Energy Savings (kWh/year)	Demand Savings (kW/mo)	Carbon Dioxide Reduction (tons CO_2/yr)
ENERGY ASSESSMENT RECOMMENDATIONS								
1	Treat rejected water with ozone	21,606	120,000	5.55	18.01	569,107	(4.0)	302.9
2	Install variable frequency drives	33,764	60,608	1.80	55.71	602,930	-	320.9
3	Install high efficiency motors	40,074	72,054	1.80	55.62	666,651	83.91	354.8
Grand Total		**95,444**	**252,662**	**2.65**	**37.78**	**1,838,688**	**79.91**	**978.6**

Table 37. Evaluated Assessment Recommendations for UF0533

ASSESSMENT RECOMMENDATIONS (ARs)

SUMMARY OF SAVINGS AND COSTS

AR Number and Description		Potential Savings ($/yr)	Implementation Cost ($)	Simple Payback Period (yr)	Return on Investment (%/yr)	Energy Savings (kWh/yr)	Demand Savings (kW)	CO_2 Reduction (tons of CO_2/yr)
ENERGY ASSESSMENT RECOMMENDATIONS								
1	Install variable frequency drives	53,828	109,400	2.03	49.20	854,415	-	454.7
2	Install high efficiency motors	42,877	213,770	4.98	20.06	680,587	198.54	362.2
3	Install an energy management system for lights	20,145	54,910	2.73	36.96	319,766	-	170.2
4	Optimize compressed air volume generation	2,617	472	0.18	554.5	41,532	-	22.1
5	Install a back-up generator switch	1,160	4,000	3.45	29.00	-	-	-
Sub Total Energy ARs		**120,627**	**382,552**	**3.17**	**31.53**	**1,896,300**	**198.54**	**1,009.2**
WASTE ASSESSMENT RECOMMENDATIONS								
6	Install a biodigester	396,790	810,000	2.04	48.99	*145,611 MMBtu/yr*	-	-
GRAND TOTAL		**517,417**	**1,192,552**	**2.30**	**43.39**	**1,896,300 kWh/yr** ***145,611 MMBtu/yr***	**198.54**	**1,009.4**

CHAPTER 8

8. CONCLUSIONS AND COMMENTS

WWTPs account for approximately 3 to 4 percent of energy use in the United States, adding over 45 million tons of greenhouse gases annually. Working with Florida WWTPs to install energy efficient equipment and implement strategies represents a tremendous opportunity to reduce energy use and reduce greenhouse gases within the state. The information contained in 'Mapping the Energy Landscape of Water and Wastewater Treatment Plants in the State of Florida' provides specific data and information on how WWTPs can lower their energy use and therefore operating costs. Reducing operating costs, which can be as high as 40 percent for energy in WWTPs, will become even more important post COVID-19 as resources have the potential to be diverted to other initiates and projects.

Below highlights from each chapter.

Chapter 2: General Background

- Energy is used in a fairly similar manner in all 3 groups of wastewater treatment plants.
- There are opportunities for on-site power generation using Combined Heat and Power (CHP) systems (see Chapter 7).
- Implementation of renewable energy systems such as photovoltaics (PV) can be made part of the plants' energy use portfolio (see Chapter 7).

Chapter 3: Facilities Surveyed by Capacity and Energy Use

- There is a significant difference between the rated capacity and the actual amount of wastewater treated (see Figure 5).
- The total energy usage has a good linear correlation (90.77 percent) with the rated capacity of the plants. This is not surprising as the rated capacity is typically established based on well-accepted design standards (see Figure 6).
- The linear correlation of the total energy usage with the actual amount of wastewater treated is about half of the linear correlation observed with the rated capacity (see Figure 7). This suggests the presence of a significant gap between what is close to optimum design versus what is taking place in actual plants. This means that there is significant room for improvements in the operation of the plants.
- For plants with both electricity and natural gas capabilities, the correlation between electric energy usage and the amount of wastewater treated is good (88.82 percent). This may be attributed to the fact that the amount of electric energy is

almost three times the amount of energy coming from natural gas for plants having both modes of energy available (see Table 7 and Figure 8).

- The correlation of electric energy usage with the amount of wastewater treated for plants with only electric energy capability is poor. The same is true for the linear correlation of natural gas energy usage with the amount of wastewater treated. Poor linear correlation is also observed between the electric energy usage and the amount of wastewater treated for those plants that use both modes of energy (see Figures 9, 10 and 11).

Chapter 4: Energy Analysis and Baseline

- Energy used per MG of wastewater treated is below recommended values by the US Department of Energy.
- Results on the baseline analysis gives *a priori* indication that in all the plants there are good opportunities to save energy and money.
- The cost associated with the energy usage depends on the utility rate structure and the corresponding utility company.
- Some plants are charged for both electric energy and demand, whereas others are charged for energy only.

Chapter 5: Energy Balance:

- The major electric energy users are pumps, motors, and blowers.
- When natural gas is used, boilers are the only equipment using it.
- Plants run year-round (8,760 hours per year).
- Equipment runs a fraction of the annual hours of operation, and not necessarily at the same time
- Electric equipment has different operating parameters such as electric loads, efficiencies and capacities.

Chapter 6: Best Practices:

- The higher the number of best practices found in a plant, the less the number of assessment recommendations that can be discovered.
- The older the facility the more likely good assessment recommendations can be found.

Chapter 7: Evaluated Energy Savings Opportunities:

- Plants that do not further treat their sludge, have great opportunities to generate biogas and biofertilizers with very appealing savings.
- Plants that do not further treat the sludge, even after biogas generation, can do the treatment and obtain biofertilizers with a high commercial value.

Final note on the Audits:

The number of ARs found by the audit teams was between 13 and 30. During the final discussion with plant management, these ARs typically get reduced to about 60 percent of the initial numbers. After the remaining ARs are evaluated in terms of their feasibility and economic appeal, about half of them are discarded. The final numbers of ARs that typically make it to the audit report are somewhere between 3 and 7 ARs.

CHAPTER 9

9. BIBLIOGRAPHY

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CHAPTER 10

10. APPENDICES

10.1 Appendix A: Electric Energy Use, Demand and Cost Distribution

10.1.1 Group I

Table 38. Electric Energy Use, Demand and Cost Distributions for Plants in Group I

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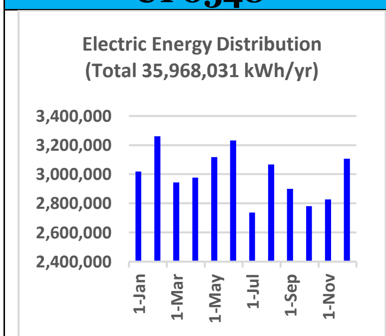
<td>
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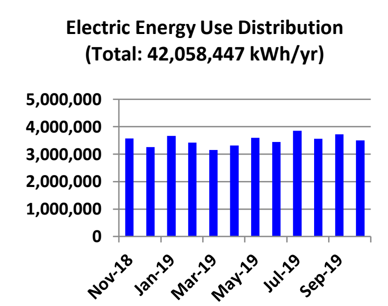
<td>
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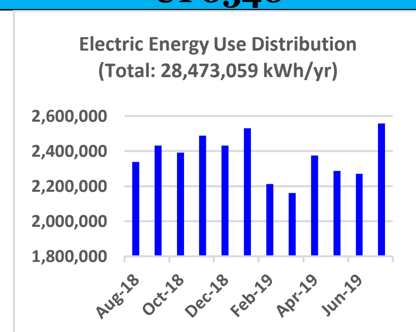
<td>
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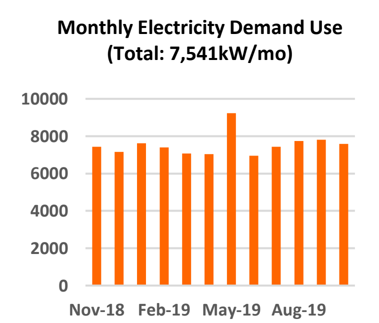
<td>
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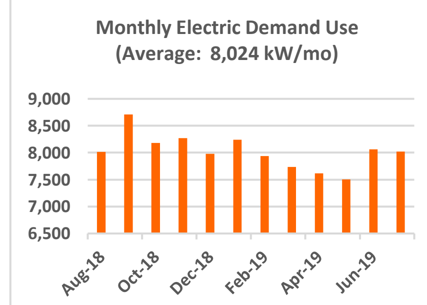
<td>
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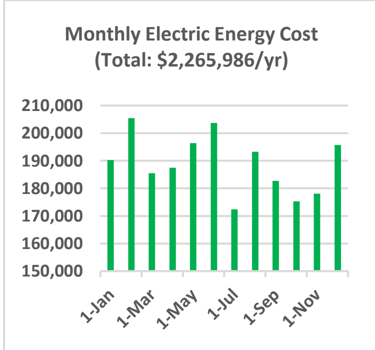
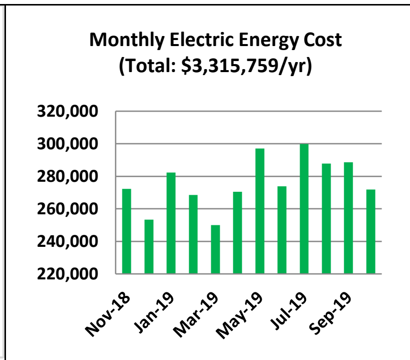
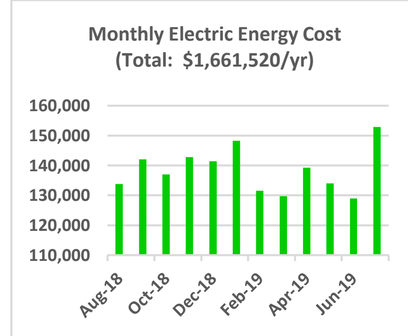
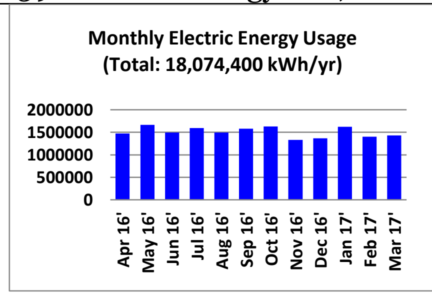
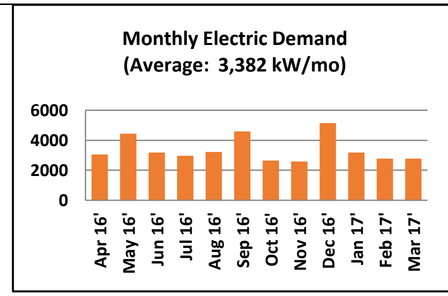
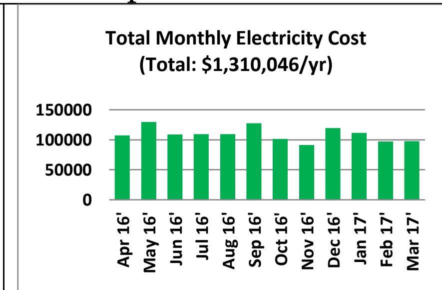
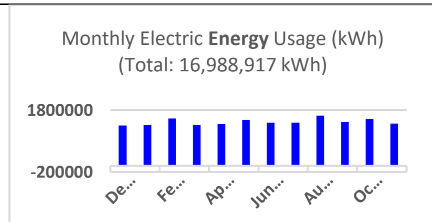
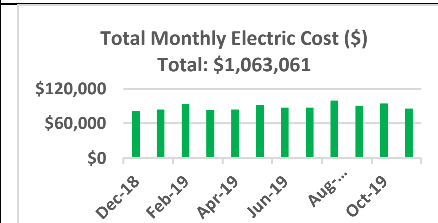
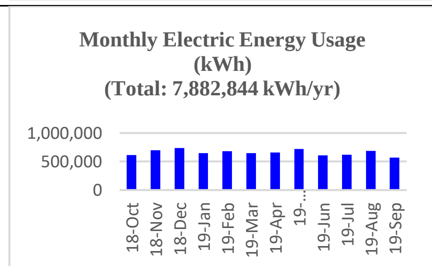
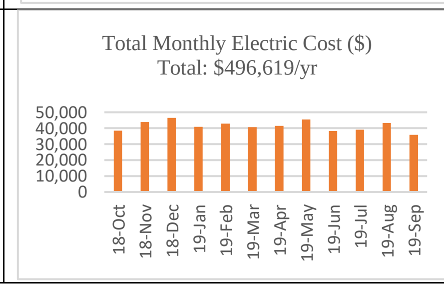

Monthly Electric Energy Cost
(Total: $2,265,986/yr)
210,000
200,000
190,000
180,000
170,000
160,000
150,000
1-Jan
1-Mar
1-May
1-Jul
1-Sep
1-Nov


Monthly Electric Energy Cost
(Total: $3,315,759/yr)
320,000
300,000
280,000
260,000
240,000
220,000
Nov-18
Jan-19
Mar-19
May-19
Jul-19
Sep-19


Monthly Electric Energy Cost
(Total: $1,661,520/yr)
160,000
150,000
140,000
130,000
120,000
110,000
Aug-18
Oct-18
Dec-18
Feb-19
Apr-19
Jun-19

10.1.2 Group II

Table 39. Electric Energy Use, Demand and Cost Distributions for Plants in Group II

UF0511			
UF0545		This plant has no Electric Demand Charges	
UF0547		This plant has no Electric Demand Charges	

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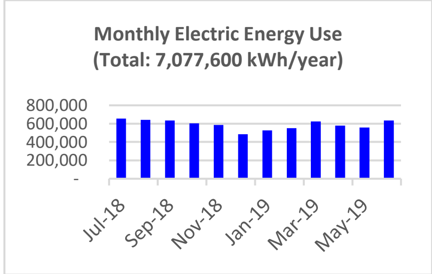
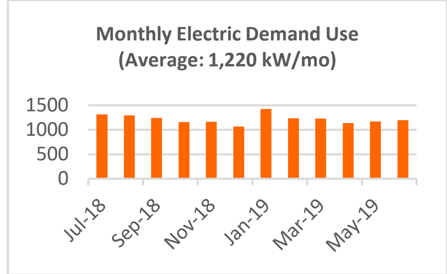
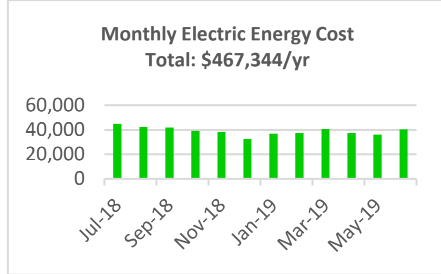


Monthly Electric Energy Use
(Total: 7,077,600 kWh/year)
800,000
600,000
400,000
200,000
-
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19



Monthly Electric Demand Use
(Average: 1,220 kW/mo)
1500
1000
500
0
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19

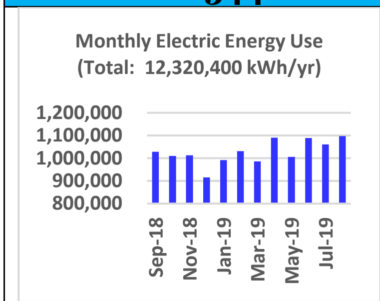


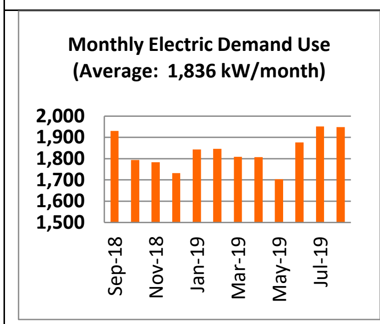
Monthly Electric Energy Cost
Total: $467,344/yr
60,000
40,000
20,000
0
Jul-18
Sep-18
Nov-18
Jan-19
Mar-19
May-19

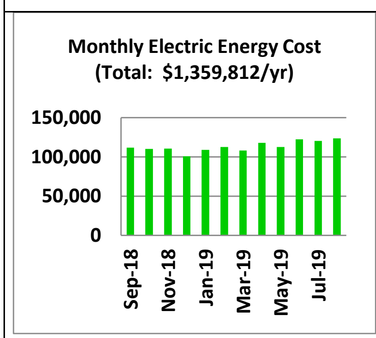
10.1.3 Group III

Table 40. Electric Energy Use, Demand and Cost Distribution for Plants in Group III

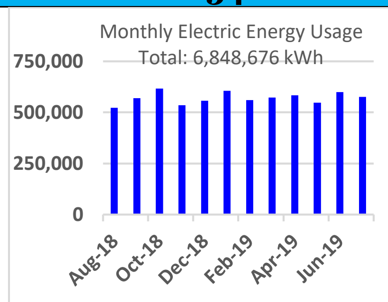
UF0544

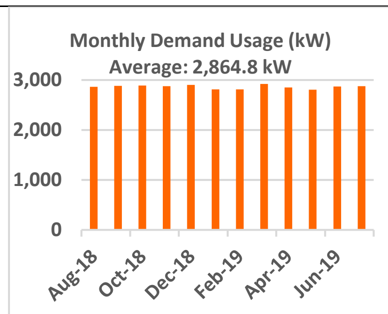


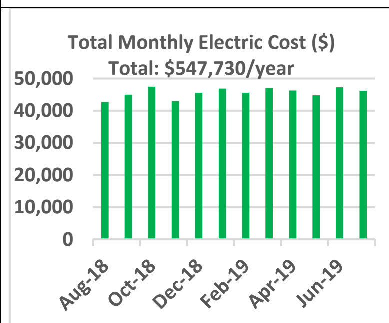




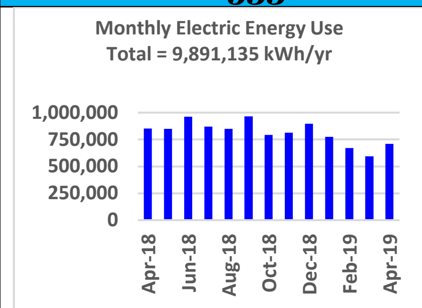
UF0542



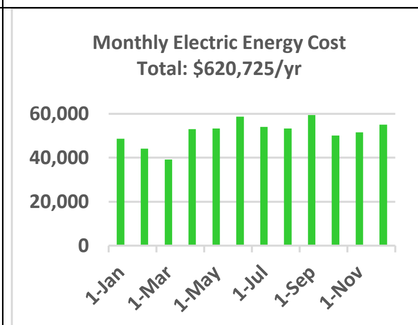




UF0533



This plant has no Electric Demand Charges



10.2 Appendix B: Thermal Energy Use Consumption

In this section, the thermal energy (natural gas) usage of the wastewater reclamation plants audited is listed.

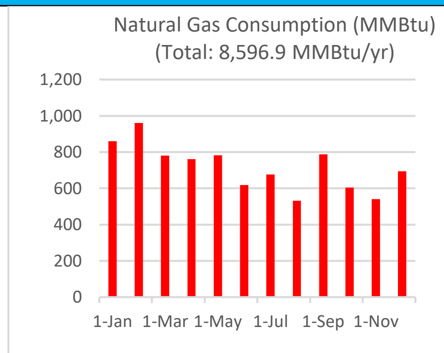
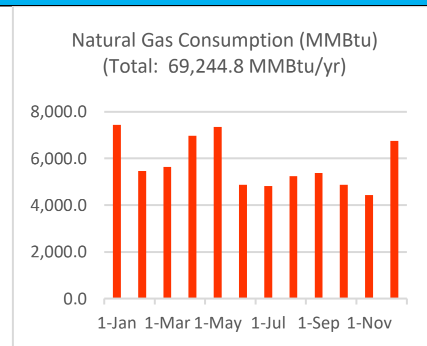
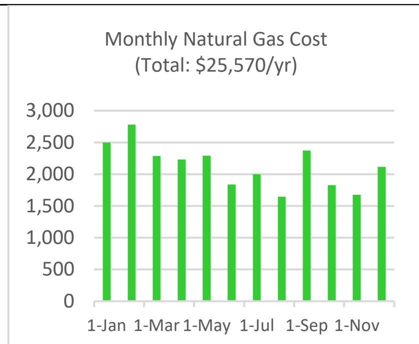
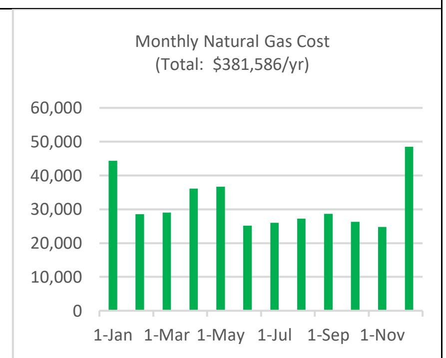
Table 41. Natural Gas usage, Biogas generated and total cost

Group	Plant	Capacity (MG)	Biogas Generated (MW)	Nat Gas Use (MMBtu/yr)	Nat. Gas Cost ($/MMBtu)	Total Cost ($/yr)
I	UF0548	52.5	3.0	180,264	2.97	535,384
	UF0549	43.0	2.5	8,597	2.97	25,570
	UF0540	33.0	2.0	69,228	5.511	381,587
II	UF0511	26.5	2.0	60,667	9.436	572,444
	UF0545	15.0	-	-	-	-
	UF0547	14.5	-	-	-	-
	UF0535 *	13.7	-	1,039	41.058	42,659
III	UF0544	10.0	-	-	-	-
	UF0542	9.0	-	-	-	-
	UF0533	7.5	-	-	-	-

* This plant occasionally uses propane gas as fuel for its thermal energy needs, hence the higher cost.

10.2.1 Group I

Table 42. Natural Gas Consumption and Cost for Plants in Group I

UF0548	UF0549	UF0540
No monthly data on Natural Gas consumption was provided by this plant		
No monthly data on Natural Gas cost was provided by this plant		

10.2.2 Group II

Table 43. Natural Gas Consumption and Cost for Plants in Group II

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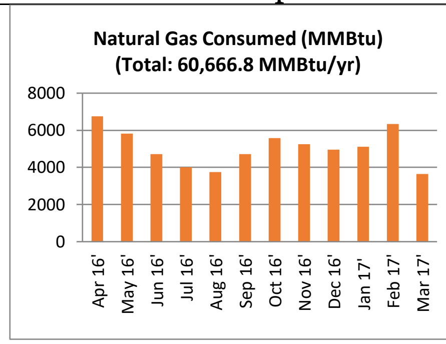
<td>
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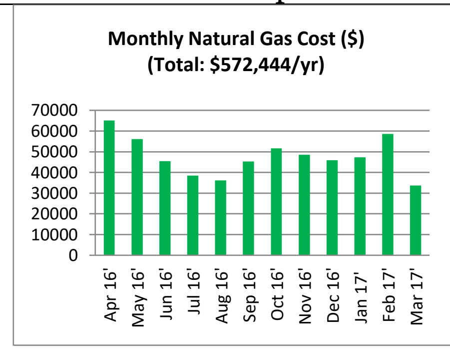
<td>
</td>
</tr>
<tr>
<td>UF0545</td>
<td>This plant
does not use natural gas</td>
<td>This plant
does not use natural gas</td>
</tr>
<tr>
<td>UF0547</td>
<td>This plant
does not use natural gas</td>
<td>This plant
does not use natural gas</td>
</tr>
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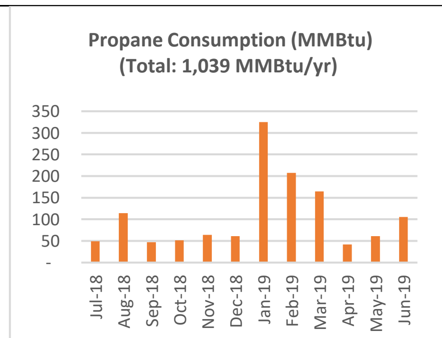
<td>UF0535</td>
<td>
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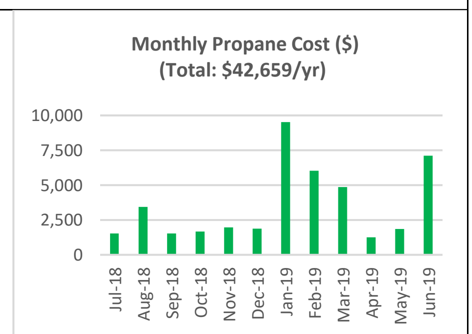
<td>
</td>
</tr>
</table>

10.2.3 Group III

None of the plants in this group either generate biogas or use natural gas in their treatment processes. This is because the sludge they produce is sent to a neighboring treatment plant or a private company to be processed further to produce biogas, and consequently they do not have boilers and/or biodigesters to satisfy the thermal load.

DISCLAIMER